SCIENCE

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MSS. intended for publication and books, etc., intended for review should be sent to the responsible editor, Professor J. McKeen Cattell, Garrison-on-Hudson, N. Y.

THE INTERFERENCES OBSERVED ON VIEWING ONE COARSE GRATING THROUGH ANOTHER, AND ON THE PROJECTION OF ONE PIECE OF WIRE GAUZE BY A PARALLEL PIECE.

IT has often been a matter of surprise to me that the shadow bands observed, for instance, on looking through one distant picket fence at another, are so seldom referred to in the literature of physics; and moreover, that phenomena so ubiquitous and of such remarkable properties are sparingly, if ever, made use of by the practical physicist. I therefore thought it worth while to look into the subject experimentally, for my own satisfaction, and the results may be of interest to the reader. I hope to show that there is probably no more straightforward example of the diffraction method in geometric optics, or more instructive method of introducing it.

CERTAIN ALLIED SIMPLE PHENOMENA.

1. If a piece of wire gauze is placed on another with the wires nearly parallel, the well-known water lines invariably come out, oftentimes, if one piece of gauze is regularly or geometrically crumpled or dimpled, showing beautiful patterns. The explanation of this is at hand; the upper meshes being nearer the eye subtend a larger angle, and when both are projected on the same plane, two scales result, one a little larger than the other. Hence, similar to the case of the vernier or the analogous case of

musical beats, there is a crowding of the lines in some parts of the field, alternating with a paucity in intermediate parts, if both gratings be uniform, plane and alike. If the drift of the wires in the two gratings be in slightly different directions, the interlacing is dense in the former case and light in the latter, with a diagonal trend. If the gratings be imperfect or not plane, the zones of light and shade must obviously be curved. Even with parallel and equal systems in the same plane, water line effects may be produced, since there is less darkness in the loci where lines cross than where they are distinct.

WHAT ARE THE GENERAL PHENOMENA?

2. This is all simple enough; if, however, the two gratings are placed at a distance apart along an axis, and the first illuminated by strong diffuse light, the second will project a real image of the former grating at definite points on the axis, almost as if it were a zone plate. When these images are looked at by the eye in the proper position, they appear as magnifications of the first grating, oftentimes enormously large the size increasing with the distance of the focal plane from the projecting grating. If the eye be moved along the axis the images vanish rapidly to infinity on the nearer side and more gradually to zero on the farther side. Distant foci are apt to show heavy blue lines on a red ground, and *vice versa*. The indefiniteness of focus when viewed by the normal eye is due to its power of accommodation, and the size is an illusion; for the eye is adjusted for an infinite distance and locates the image of unknown position there. The eye unaided is therefore not well adapted for observations of this character. If, however, one throws the eye out of range with a reading glass of, say, 10 cm. focal distance held close to it, the variability of focal distance is practically wiped out, and the positions of the images may now be charted satisfactorily.

Some years ago, while looking through an ordinary door screen at the Venetian blinds on the opposite side of the street, I noticed that the zones of light and shade were remarkably distinct when viewed by the naked eye (which in my case is near-sighted), but that they all but vanished or were so faint as not to be an annoyance when viewed through spectacles. This observation is general: If the normal eye is put out of proper function by looking through strong convex or strong concave glasses, in either case the shadow zones at the proper distance from the screen become painfully pronounced. They disappear as the eye is properly equipped, naturally or otherwise, for long range vision. It seems probable that this principle (to which I shall return in § 5) could be used practically in fitting the eye with the proper glasses.

For the present purposes therefore either a convex or a concave lens will be needed by the normal eye to fix the proper focal planes of the grating; but as the plane for the convex lens is in front of the eye, this is the more serviceable. Direct projection is only possible in a darkened room and at the strongest focus, supposing that diffuse daylight illuminates the first grating. With sunlight all the real foci may be projected, but the use of sunlight (at the outset) slightly alters the conditions. Foci may also be found by the telescope directed along the axis; though furnishing admirable qualitative results, this is the least accurate of the methods and useful only for finding virtual foci in the cases discussed below, § 5.

Thus the following simple arrangement is suggested for measurement. Along the axis LL' there is placed the ground glass screen C, and the wire gauze* grating A just in front of it. At a distance, x, from A the

* Ordinary door screen wire gauze, say 6 inches high and 12 inches wide, in a wooden frame, answers all purposes.

second grating, B, is adjusted with the wires parallel to A; and at a distance, y, from the latter is the focal plane S, visible to the eye behind the lens (or in the distant correspondingly focused telescope, looking along $L'L$ in Fig. 2, as will be explained below). It will be convenient to call the grating space at A, a; the space at B, b; and the space of the image at S, s, all being parallel. Then the experimental results of Table 1, in which relations of x and y for the case of $a = b$ have been inserted as an example of many similar data, will be intelligible at once.

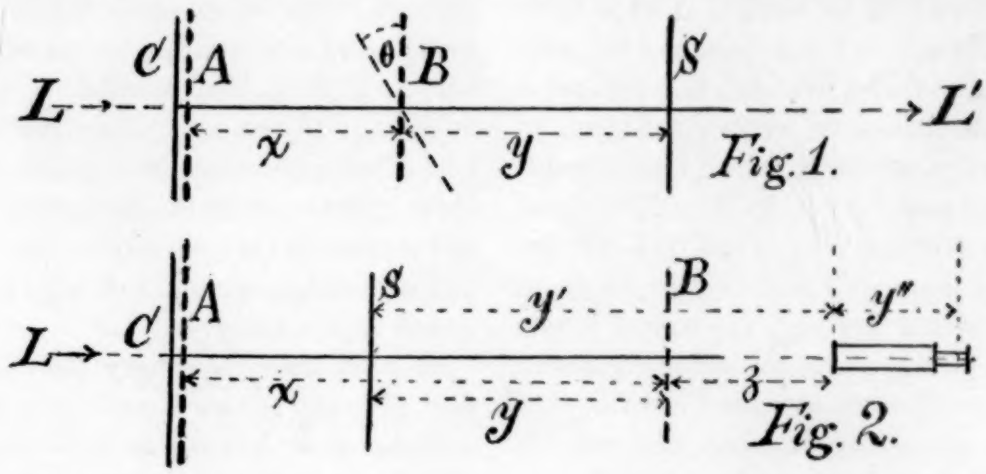


Fig. 1. Fig. 2.

TABLE 1.—EXAMPLE OF FOCAL PLANES FOR GRATINGS WITH EQUAL MESHES. $a = b = .214$ CM. AND WIRES .030 CM. IN DIAMETER, LENS FOCUS 15 CM. $a = b$.

$x=$	100	200	300	400	cm.
$y=$	125 215 —	105 225 —	155 315 615	201 410 —	cm.
Ratio, $y/x=$	1 2 —	$\frac{1}{2}$ 1 —	$\frac{1}{2}$ 1 2	$\frac{1}{2}$ 1 —	

TABLE 2.—EXAMPLE OF FOCAL PLANES FOR GRATINGS WITH UNEQUAL MESHES. MESH OF A, .214 CM., OF B, .033 CM., SO THAT $a/b = 6.5$.

$x=$	300	400	cm.
$y=$	35 75 135	65 145	cm.
$y/x=$	1 2 4	1 2 —	

Naturally these results are crude, but as their import is unmistakable, it is not necessary to push the experiment further. The first definite result derived from them is this, that the focal planes are distributed along the axis at distances $\frac{1}{2}$, 1, 2, etc., multiples and submultiples of the distance of the gratings apart, when the two gratings are identical, or $a = b$. The size of the images is usually directly as the distance y from grating B, and if for $a = b$, $x = y$, then $a = b = s$, or image and object are equally large. Remote focal planes are apt to be diffuse and colored nearly uniformly red and blue in alternate bands. Hence the number of foci accessible in this way is not large.

If the meshes are unequal, the focal planes are still apt to be distributed at distances varying as 1, 2, 4, etc., along the axis. Corresponding distances, y, are smaller relative to x if the projecting grating is finer. The law of distribution is not easily worked out in this way, however, because it is difficult to obtain gratings of different meshes but of the same diameter of wire. Neither is it safe to infer the size of image from these experiments. The problem must be attacked in another way.

3. Since the distances x and y are large (2-10 meters), it will be possible to obtain gratings of different fineness (effective horizontal distance of wires apart) by merely *rotating* either grating on an axis parallel to the wires. Since the focal planes have now been shown to be real, it is expedient to project the whole phenomenon with sunlight, and if parallel rays are not wanted a ground glass screen or better, a screen of scratched mica which is more translucent, may be interposed at C in Fig. 1, in front of the first grating, A. Thus if L be the direction of sunlight and θ the angle of rotation of either grating, the figure meets the present case. If A be left normal and B rotated, results are obtained for the case where the projecting meshes are smaller horizontally than those projected. If B be left normal and A rotated, the projected meshes are the smaller. For any angle θ of either A or B, the grating B and screen S may be moved along the axis to locate the other focal planes for the same mesh ratio. With the proper angle θ images may be focused for any distance y relative to x.

TABLE 3.—DATA FOR A FINER PROJECTING MESH (B ROTATED). $x=200$ cm. $a=1$.

y	θ	Appr. $\cos\theta$	s Image.	Remarks.	Symbol in chart.
100	0°	1	.5	bk. and wh.	Fig. 3—α
	49°	$\frac{2}{3}$	.5	"	" 7—β
	71°	$\frac{1}{3}$	.5	"	" 5—γ
200	0°	1	1.0	red and bl.	" 3—δ
	41°	$\frac{3}{4}$	.5	bk. and wh.	" 8—ε
	61°	$\frac{1}{2}$	1.0	red and bl.	" 4—η
	78°	$\frac{1}{4}$	.5	strong.	" 6—ζ
300	52°	$\frac{3}{5}$	1.5	"	" 8—strained
	75°	$\frac{3}{10}$	.75	br. and wh.	" 8— "
400	47°	$\frac{2}{3}$	2.0	"	" 7—μ
	74°	$\frac{1}{3}$	1.0	"	" 5—ν
600	42°	$\frac{3}{4}$	3.0	strong.	" 8—ξ
	70°	$\frac{3}{8}$	1.5	"	" 8—strained
700	—	—	3.5	"	———
			1.75	"	

At long ranges (500 cm. and more) the white shows faint interference fringes usually with a pink center. At 7 meters, when the ground glass screen is interposed in front of the first grating, A, the effect is a remarkably clear diffraction pattern fully two feet square or more, consisting of narrow, strong, black lines on a dull white ground. When the grating space of B is reduced to $\frac{1}{2}$ by rotating it, very fine lines fainter but very clear show on the same ground. For other mesh-ratios the field is blank, and sharp adjustment of θ is necessary. Diffuse, non-parallel light, therefore, is equally active, and being free from the intense but circumscribed glare of full sunlight, gives more striking results. Moreover, the same figures as above show through the dull mica screen for all the distances noted in the table.

Special attention may be called to the fact that the figure is still distinct even at a distance of 30 meters between the image S and the projecting grating B.

The results of the following table were obtained by keeping grating B normal and rotating A.

TABLE 4.—DATA FOR A COARSER PROJECTING MESH (A ROTATED). $x=200$. $b=1$.

y	θ	Appr. $\cos\theta$	s mage.	Remarks.	Symbol in chart.
200	48	$\frac{2}{3}$	1.50	Strong.	Fig. 7—μ
	60	$\frac{1}{2}$	.50	"	" 4—η
400	42	$\frac{3}{4}$	1.50	"	" 8—prol. bk.
	71	$\frac{1}{3}$	.30	"	" 5—ν'

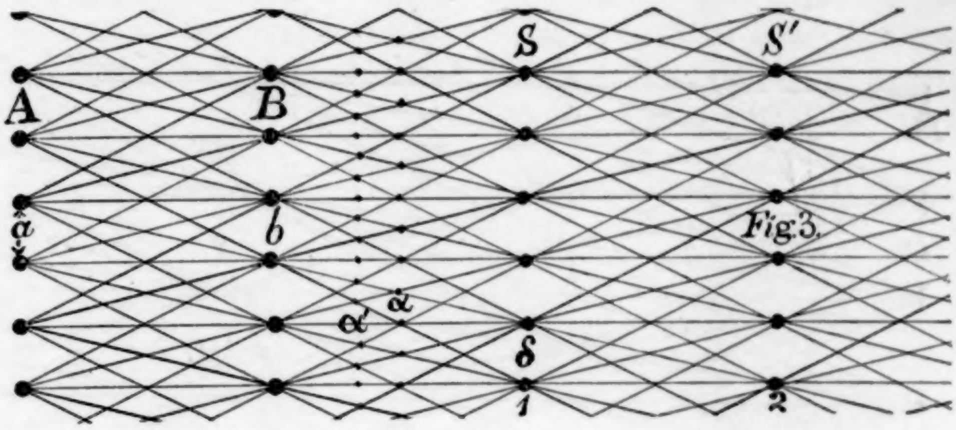
As the obliquity of A is increased the focal plane frequently does not sharply vanish, the image merely becoming smaller. Because of this indefiniteness of smaller images further measurement was not attempted. It will be seen that the angles θ for the same y do not correspond to the preceding table, as was directly proved by exchanging the gratings. This is the important datum of the new series of observations, and makes it needless to adduce a greater number.

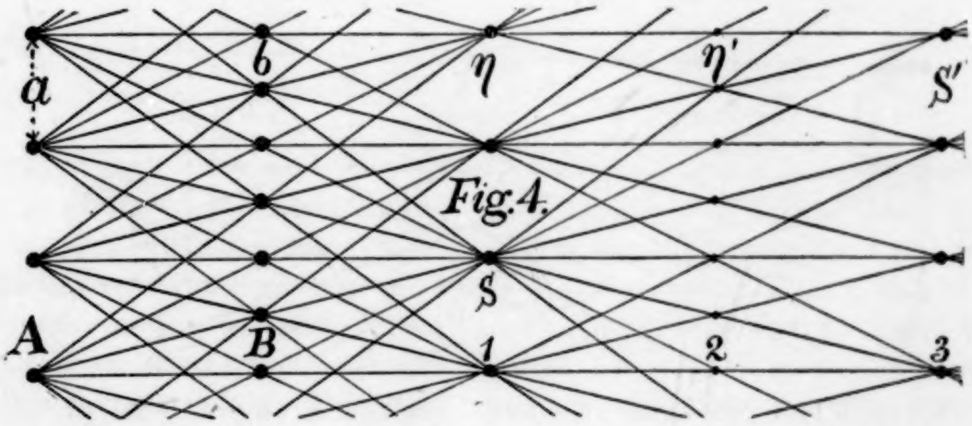
SCHEME FOR THE PROJECTION OF ONE GRATING BY ANOTHER.

4. In order to interpret these results it will be expedient to introduce a simple

hypothesis, of a kind which in the sequel may be modified to meet the true case. I shall proceed, therefore, to trace what may be temporarily called the effective planes of shadow in diffuse light. In other words, planes are to be passed between the two gratings through their consecutive wires and the loci of intersection determined. If the wires are vertical the result may be mapped out by drawing the traces of the two planes in question on a horizontal plane, and the object would be gained by solving a few straightforward problems in the modern geometry of pencils of rays. It will greatly facilitate inspection, however, if some of the chief cases which have been considered are drawn out in plan. This has been done in Figs. 3–8, which will be found additionally useful in the physical questions of the next section. *A* and *B* show the positions of the gratings and *S*, *S′*, etc., are the successive positions of the focal plane or screen. Grating spaces and image spaces are denoted by *a*, *b*, and *s*, respectively. Reference planes designated by Greek letters will be presently referred to. Wherever lines mass in a single point, there one may look for a deficiency of light coming to an observer behind both gratings. Corresponding groups of intersections thus determine a focal plane.

To begin with Fig. 3, in which $a = b$ or the two paralleled wire gratings are identical, the diagram is seen at once to reproduce the results of Table 1. At relatively remote distances the diverging planes tend to pass out of the field, and the images must therefore weaken for this reason alone. Table 3 describes the images a and δ, the latter colored; the focal plane a' with $s = \frac{1}{3}$ is also sharp. Following *S*, the planes *S′*, *S″*, etc., did not appear distinctly enough to be recorded.





The figure shows, moreover, that between A and B there should be virtual focal planes, and these must also be discoverable to the left of A. That such actually occur will be shown below, § 5, by the telescope method. The absence of S', S'', etc., will not appear surprising, since the distance AB is two meters and shadows become diffuse. It is rather surprising that images properly produced can be obtained at over 30 meters from the projecting grating.

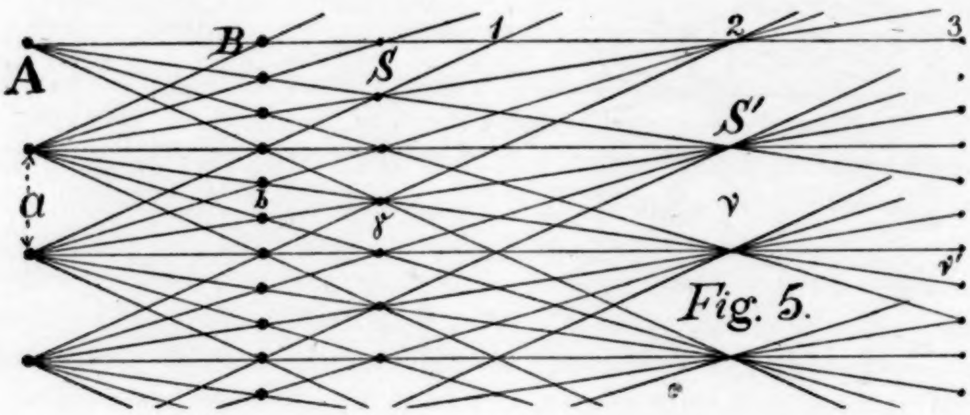


Fig. 5.

In Fig. 4 the meshes of B are half as large as A. Table 3 shows at η that the plane S comes out strongly and colored. S' was not found nor were the other images striking. Virtual foci are here also suggested. Table 4 indicates that if B be the first grating and S the second (larger) the focal plane η' is sharply traced.

In Fig. 5 the grating spaces are as $\frac{1}{3}$. Table 3 shows that the planes S and S' are both pronounced (marked γ and ν). According to Table 4, if B is the first grating and S' the second, the focal plane ν' will appear.

In Fig. 6, with the space ratio $\frac{1}{4}$, the image ζ is strong; the image ζ' was also found; but with these cases of high inclination θ, the images are confused and focal planes are apt to be continuous. Thus an image may be found at S', but not sharply in position. In general a contracted diagram is liable to exceptions to be explained below.

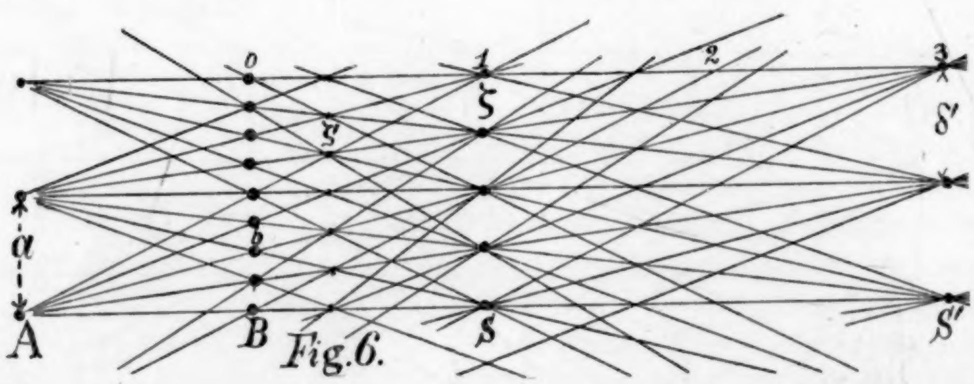


Fig. 6.

In the preceding cases the original grating space is reproduced, as, for instance, at S' in Fig. 6, when, if $x = 1$, $x + y = a/b$. The figures are symmetrical with respect to the strongest focal plane (ζ in Fig. 6, for instance). The original grating space is reduced in the image or at most equal to it. There is no magnification.

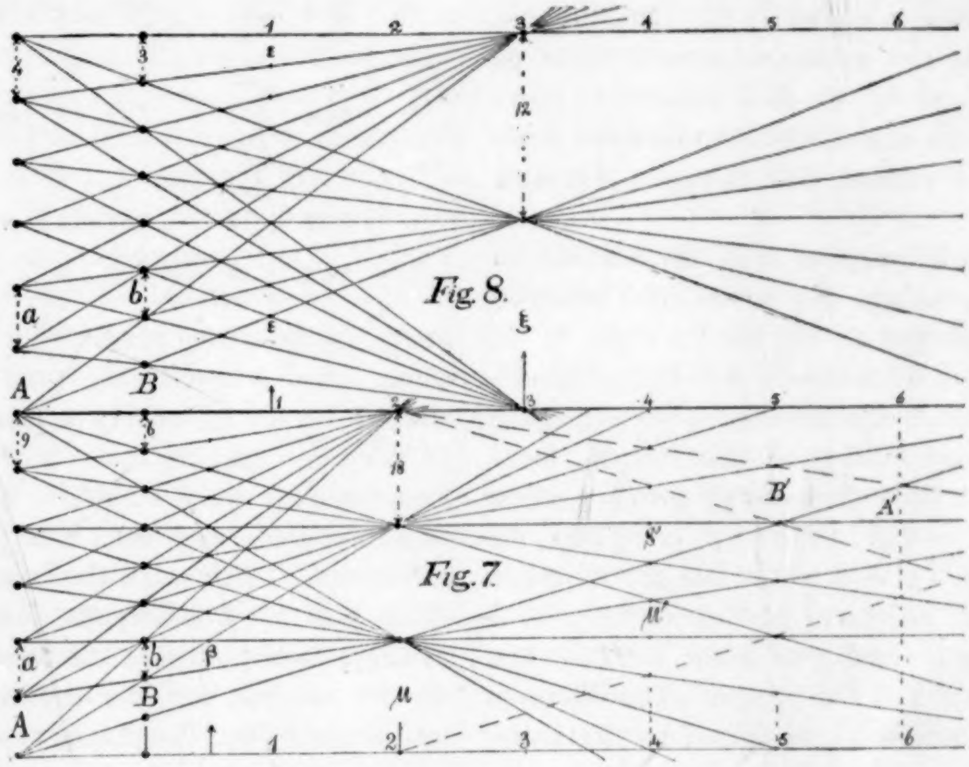
In the following cases the ratio a/b is not a whole number, and the image may therefore be magnified to an extent which is the least common multiple of a and b. More-

over, $s/a = y/x$, so that the strong image is usually remote. The projected grating is here taken as the larger, $a>b$. If $a<b$ the corresponding image space will be $s' = b(1 + (x/x+y)(2a - b/b)$.

In Fig. 7 the ratio a/b is $3/2$. Table 3 shows the focal planes β and μ to be pronounced. The magnification at μ is 2, with strong brown lines on a white ground which contains faint traces of a pinkish diffraction band in the middle.

the light areas which are alternately white and colored reddish.

The final case to be exhibited in detail is Fig. 8, where $a/b = 4/3$. The focal planes ε and ξ are marked phenomena, the latter at the long distance of 6 meters from B, strong and coarse as usual. With the mica screen clean cut dark bands .2 cm. broad and .7 cm. apart, cover an area of a square foot. If B is the projecting and A the projected grating ($a/b = 3/4$, light re-



If the ratio a/b is $2/3$, A' and B' may represent the positions of the grating, the light retrogressing, so that S' is the corresponding focal plane. It is marked μ' in Table 4, where moreover μ is again reproduced as the second focal plane of this series. The coarse images for this and succeeding cases of long distance (6-10, even 30 meters), are a striking feature. The phenomenon becomes fainter but otherwise more remarkable and much larger if the ground glass or, better, the mica screen is placed before the first grating. The diffraction character then becomes manifest in

trogressing), Table 4 shows the focal plane at 4 meters well marked, and found from Fig. 8 by prolonging the lines backwards, in the direction BA.

The other cases of Tables 3 and 4 are found by subjecting Figs. 7 and 8 to a homogeneous strain, with the principal strains in the horizontal and vertical directions. Similarly, 7 would follow from 8 or from the above figures. Focal planes corresponding to S are usually well shown.

As a rule, therefore, the diagrams are a convenient means of predicting the relations of size and distance of the images.

They do not account for the accompanying color which is a not infrequent occurrence; and they predict more focal planes than are easily found. The latter discrepancy might be ascribed to the imperfect gratings (wire gauze), or to lack of intensity taken as proportional to the number of lines which cross at a point in the diagrams. It would merely have been confusing to record other than the strong cases. The diagrams fail altogether to suggest how a thin wire is to cast a shadow of the order of 10–30 meters in length, even in diffuse light. It is in this respect that the explanation will have to be supplemented. In the meantime, however, it seems worth while to test the position of the virtual foci between *AB* and beyond *B*.

5. For this purpose it is convenient to place the gratings far apart and observe with a telescope as shown in Fig. 2. If f be the focal distance of the objective, and y'' the reduced distance of the conjugate focus, corresponding to the virtual focal plane S at a focal distance y', we may write $1/y' + 1/y'' = 1/f$. With y' computed in this way, $y = y' - z$, where z is the distance between the objective of the telescope and the grating B; and y, as usual, the distance between this and the image. The distance x may be measured or found by the same method.

This experiment gives excellent results for the number and relative size of the successive images between A and B. It is a crude method of finding the distances y, sufficing, however, to pick out their position in a series. If A be the clapboarding of a distant house and, B an ordinary window screen through which A, distant about 300 feet, is observed, the conditions for many virtual foci will be realized. Table 5 gives an example of results of this kind.

The table shows that the limits of y are pretty well given, the visible foci should all lie near B as found. All the focal planes observed are predicted by a diagram of intersecting pencils of rays of the kind above exhibited, as indicated by the third and fourth columns of the table. Nevertheless,

TABLE 5.—VIRTUAL FOCI BETWEEN THE GRATINGS. $x = 10,000$ CM. $z = 274$ CM. GRATING SPACES, $a = 10.7$, $b = 22$ CM.

Focus. No.	y'', reduced.	y, predicted.	y, observed.		Size.
Screen	37.0	0	0	(0)	—
2	35.8	63	56	(1)	small.
3	35.5	125	137	(2)	larger.
—	—	188*	—	—	—
4	34.8	250	272	(4)	largest.
—	—	313	—	—	—
—	—	375*	—	—	—
—	—	437	—	—	—
5	34.1	500	532	(8)	smaller.
—	—	563*	—	—	—
—	—	625	—	—	—
—	—	688	—	—	—
6	33.7	750*	756	(10)	much smaller.
Clap boards	32.8	—	10,000	—	—

many images are predicted which do not occur; and whereas the predicted images should be all of nearly a size, practically of the same grating space as B, the images found are all much smaller. They increase to a maximum and then diminish again in the direction BA, with the largest not more than $\frac{1}{2}$ of b. Possibly the presence of two or more focal planes in the telescope at once would account for the discrepancy of size and number, but the planes marked * which should be strong do not appear specially so in the experiment. In general, therefore, the diagrams give a good outline of the phenomena, but fail in the particulars. One may note that the foci found are in a distance ratio of 0, 1, 2, 4, 8, 10, which is liable to be more than a coincidence.

Another class of virtual foci consists of images not lying between the gratings, but on one side of both when looked at from the other side. This implies the same method of telescopic observation: obviously the cases of Figs. 3–8 can all be found as virtual images by a telescope in front of A, looking from A to B. In such a

case A may be moved quite up to the object glass or drawn on it. Knowing the position of the images, it is possible that such an arrangement might be used in measuring distances, A being for this purpose taken suitably greater than B.

Here I may revert to the observations with and without spectacles instanced above. If the eye is so circumstanced as to focusing power as to be able to see grating A in the distance through grating B distinctly, then the shadow bands will be out of focus and faint. If, however, a near-sighted eye or one made abnormal by convex or in a second case by concave lenses, grating A is quite out of the range of vision. The eye will then find and fix upon one of the focal planes, virtual or real, due to the projection of A by B. If there be not too much stray light, the shadow bands in such a case are painfully obtrusive.

LONG SHADOWS CAST BY THIN WIRES IN NON-PARALLEL LIGHT.

6. It is finally necessary to explain the long lines of shadow assumed tentatively in the above hypothesis. Even in sunlight a filamentary wire will not cast an effective shadow further than 5 or 10 inches; the shadows here encountered may be 100 feet in length.

Clearly the phenomenon is one of diffraction, and it will be expedient to recall the fundamental case of a single slit and a single edge. The pattern is well known, consisting outside of the geometrical shadow of a very bright and then very dark band, followed by colored alternations of light and shade more cramped and much less distinct and intense. Within the shadow the light sinks gradually into darkness.

Suppose the slit to be displaced laterally to the left a small distance; the whole diffraction pattern will then move toward the right over the same distance if $x = y$, and for other distance ratios, proportionally. Now suppose that both slit actions occur simultaneously. The feature of the diagram will be the two maxima of light enclosing between them a shadow band without color, which is a compound of the darkness within the geometrical shadow for the first slit, now limited on the right side also by the maximum of the second slit and its external dark band. *The effect therefore is the same as if the bar between the two slits were projected.* For $x = y$ the distance between the light maxima will be the same as the distance between the slits otherwise in proportion to relative distance. If the slits are finer the phenomenon is darker and sharper; if coarser, brighter and more vague. If the slits move closer together the bands move closer proportionally. Color is rarely apparent.

It follows from the preceding that with 3 slits and an edge, 3 maxima of light and 2 dark bands without color will appear; with 4 slits, 4 maxima and 3 shadows, etc. The whole phenomenon may be regarded as crowded into the geometrical shadow of the first slit. Hence if the slits increase in number the number of bands will soon reach a limit as more and more light falls inside the edge of the shadow in question. With a coarse grating (rods and spaces say .2 cm.) but 5 shadow bands may appear for an indefinite number of spaces. In general the diffraction pattern covers a certain area; if the slits move closer together there will be more and finer bands visible; if they move farther apart, fewer. With an edge just in front of a telescope or on the objective and light nearly screened off, an indefinite number of lines may be seen on looking at a distant white surface through grating A. From the distance of A from the objective (.1 to several meters) and the size of image and object the magnification of the telescope may be inferred.

7. With the case of an edge and multiple

slit sufficiently disposed of, the case of a single wire and multiple slit is not far to seek. There will be a series of light and shade bands for each edge of the wire, and the two series will eventually run through each other. A single slit has within the geometrical shadow the well known brownish band, finely fluted and broad for a thick wire, coarsely fluted and narrow for a thin wire. With 2 slits there will be 2 shadow bands with a maximum of light between for a fine wire, or 3 bands with an intensely dark one in the middle for a stout wire (say 3 mm.). With 3 slits and a fine wire 3 shadow bands appear at long ranges ($y/x = 1/3$), more at short distances. With a coarse wire 4 at long ranges with the two internal bands intense, 5 or more at short ranges, etc. It follows eventually that with a *multiple* slit and wire the diffraction patterns may be looked upon as compounds of the light and shade bands of *each edge*. At $x = 2$, $y = .5$ meters, a blur usually appears for the thin wire, sharp fine lines edging a broad central shadow for the thick wire. This continues up to 2 meters in the latter case; but with the thin wire with y between 1 and 2 meters, there are apt to be colored blue and red bands of a very complicated pattern. Beyond two meters the figure is in all cases again simply white and black, with the former or the latter wider conformably with the structure of grating A, supposed to be at 2 meters from B. Size of rod is without influence here. With the thick wire the central ever-narrowing shadow may be visible beyond 2 meters, and as it apparently thrusts the bands apart the figure is relatively broad. In so far as the edge effect predominates and overlapping is obscured in the middle, the bands appear in focus at all distances.

8. From these results to the actual case of the grating is an easy step. Grating A furnishes the multiple slits, about 5–10 of which are effective for every wire of grating B. Each of these has its own series (about 8 in the above case) of shadow bands, all identical in form. When for any position on the axis the shadow bands of all the wires of B coincide, there will be a focal plane at that point and B will project an image of A. At other points there will be no image, for patterns overlap irregularly, light falling on shade and producing more or less uniform illumination. Figs. 3–8 show the conditions to be such that many band series must overlap, and hence the greater definition of focus.

At close ranges, therefore, both the width of the wire (in relation to the independent shadow bands of each of its edges) and the distance apart of the wires (in relation to the above Figs. 3–8) must be of proper value to produce coincident effects. At long ranges coincidences depend more on the diagrams.

From another point of view we may consider the band series of the right and left hand edges of the wire of the grating independently. The former will be brought to focus at those points of the axis where the successive images of corresponding edges overlap. The latter equally so. The two images so formed, and corresponding respectively to the two edges of all the wires of B, will not blend in a compound image, unless the images coincide. If the separate edge images are apparently displaced relatively to each other, *i. e.*, if there is appreciable non-coincidence of shadow bands, there will be no focal plane even if the images of the separate edges are perfect. Hence there is an adequate account given of the absence of focal planes predicted by the above constructions. Again, just as there may be color effects for a single wire at certain distances, so for the wires conjointly there will be color phenomena between the images of all corresponding edges. Finally, an inkling is given as to why focal planes which from diagrams 3–8

one would expect to be strong, do not so appear; and *vice versa*. Images which would be strong for the right and left edges separately need not be so when the former are superimposed on the latter.

With these remarks I believe to have given a sufficient account of these interesting diffractions. I began the work since in all my reading in physics I had never seen a reference to these ubiquitous phenomena, and I hoped with the present paper to furnish at least one contribution of known whereabouts. In the course of the work I found much greater subtlety than I was prepared for, and some of the cases given are available for more rigorous treatment elsewhere.

Carl Barus.

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Providence, R. I.

THE CROSSLEY REFLECTOR OF THE LICK OBSERVATORY.

The leading article in the June number of *The Astrophysical Journal* has the above title and was written by Professor Keeler. It is a very full account of the instrument and of the work accomplished with this telescope since its installation on Mt. Hamilton. I am very glad to comply with the request of the editor to furnish an abstract for Science.

The frontispiece of the number is an excellent heliogravure plate of the 'Trifid' nebula in Sagittarius, from a negative made with the Crossley reflector. In this connection it ought to be said that no known method of reproduction gives all the detail to be seen on the original negatives of such subjects. There are also halftone illustrations, from photographs, of the details of the telescope and its observatory.

This telescope was made by Dr. A. A. Common, of London, in 1879, and used by him until 1885, when he decided to build one of 5 feet aperture. He then sold the 3-foot instrument to Edward Crossley, Esq., of Halifax, England. For the construction of the instrument and for photographs obtained with it, Dr. Common was awarded the gold medal of the Royal Astronomical Society in 1884.

Mr. Crossley built a very complete observatory and dome for the telescope and used it for a number of years. The climate of Halifax was not adapted to the use of reflectors, however, and in 1895, at the request of Professor Holden, then director of the Lick Observatory, Mr. Crossley presented the telescope and its dome to this institution. The expenses incurred in transporting it from England and in erecting a suitable building on Mt. Hamilton were borne by friends of the Lick Observatory, principally residents of California. It was mounted here the same year. Its dome is situated on a spur of the mountain some 350 yards to the south of the main observatory and about 150 feet lower. The building contains, in addition to the dome and vestibule, a photographic darkroom, a study, a room for apparatus and storage, and a room for the hydraulic machinery which was used in England to revolve the dome. The present site is such that the hydraulic system which is used for the large refractor is not available for the Crossley reflector. The dome is turned by hand by means of an endless rope and a set of gears working in a cast-iron rack bolted to the inside of the sole plate of the dome. The dome is covered with sheet-iron, the framework being of iron girders. It is of the usual form, with a shutter in two parts which are rolled to each side, exposing a slit six feet wide. The slit extends well beyond the zenith. From the inside of the dome is swung a system of platforms around the telescope for the observer to stand upon. The cylindrical walls upon which the dome rests are double, 36½ feet inside diameter. The dome itself is 38 feet 9

inches in diameter. The lower half of the observing slit was fitted with a screen of tarpaulin by Professor Keeler, which proved very useful against the winds which are so prevalent on Mt. Hamilton.

The telescope and its mounting are very completely described and figured by Dr. Common in Vol. 46 of the *Memoirs* of the Royal Astronomical Society. The telescope was designed especially for photographic work, in which it is very desirable to continue an exposure uninterrupted, across the meridian. This cannot be done in the usual form of mounting where the declination axis is attached to the middle of the tube of the telescope and to one end of a short polar axis. Dr. Common obviated this difficulty by placing the declination axis at the extreme lower end of the telescope tube, the axis of the telescope always being in the same meridian plane as the polar axis. The large mirror is *above* the declination axis, and hence requires to be counterbalanced. This counterbalancing of mirror and tube is effected by placing slabs of lead in two boxes which extend a short distance beyond the declination axis. Professor Keeler points out that the construction adopted by Dr. Common for his 5-foot reflector is a great improvement. In the latter instrument the tube is swung near its lower end between two large ears attached to the polar axis, the pivots forming the declination axis. The mirror is placed at the extreme end of the tube and thus acts as a counterbalance.

The construction of the mounting limits observations to 25° south declination. In London, for the latitude of which the mounting was constructed, this meant a zenith distance of 77° on the meridian, but at Mt. Hamilton it is only 62°. In our more southern latitude a considerable region is thus unfortunately out of reach of the telescope.

From his experience with the Crossley reflector, Professor Keeler came to the conclusion that the definition in the case of a reflector, as well as a refractor, depends almost wholly on external conditions, and that large masses of metal near the mirror have little effect, at least where the range of temperature is as small as at Mt. Hamilton.

The telescope is used as a Newtonian. It is provided with two large mirrors, each three feet in aperture, and of 17 feet 6.1 inches focal length. These mirrors were made by Mr. Calver. The one in use at present (mirror A) was refigured by Sir Howard Grubb, and is practically perfect for photographic work. It may be added that this mirror has so far been used with the same coating of silver which it had when received from England. Mirror B has not been used at Mt. Hamilton.

The diagonal mirror is round, its diameter being 8.9 inches. Its distance inside the focus is 29 inches.

The field of view after reflection is, therefore, elliptical. Its mounting is such, however, as to cut off an almost circular section of rays from the large mirror.

The tube of the telescope is a square framework of iron tubes braced by diagonal rods and is provided with curtains of black cloth to close the tube in. Professor Keeler found that any fogging of the plate was due to diffused skylight and the curtains have therefore been dispensed with. The outer end can be rotated about the axis of the telescope to bring the eyepiece into as comfortable a position as possible. This section carries the diagonal mirror and the eye end. The latter has the customary arrangement for focusing and is made to take the short tubes, one of which is arranged for visual and the other for photographic work. The photographic slide contains, in addition to the double motion device, an adjustable slide carrying an eye-piece with cross wires for guiding. This is placed very close to the plate-holder slide and clamped to it.

The image of a star is kept bisected by turning the proper screws attached to the movable frame.

Upon taking charge of the Lick Observatory in June, 1898, Professor Keeler decided to devote his own observing time to the Crossley reflector, notwithstanding that his previous experience had all been with refractors. Upon making a careful examination of the instrument, he found that a number of changes would be necessary before satisfactory results could be expected. Some of these were required on account of the change in latitude and the different climatic conditions existing at Mt. Hamilton. The brick pier upon which the telescope rested was found to be too high for the greatest convenience and usefulness and was lowered two feet. The polar axis was found to work hard, the plan of mercury flotation not being successful and the construction being such that the friction was increased in this lower latitude. This caused the driving clock to run irregularly, and a more powerful one was built at the observatory from designs by Professor Hussey. A further cause of irregularity was found in one of the wheels of the differential gearing for giving slow motion in right ascension. As long exposure photographs near the pole required a considerable degree of accuracy in the position of the polar axis, some time was spent in devising methods for adjusting a telescope of this design. The methods used for a telescope of the ordinary construction do not suffice. One very promising plan was to secure trails of the stars near the pole on the same plate in two positions of the telescope 180° apart. Consistent results were not obtained, however, owing to the instability of the large mirror. The axis was finally adjusted by using a long finder for observations of Polaris in the usual way, a watch telescope being fastened to the mounting in such a way that an object on the southern horizon could be observed during the process of shifting the iron pier.

The resolving power of the telescope was tested by visual observations of close double stars, with the result that stars of about the 8th magnitude and of nearly equal brightness could be separated with a magnifying power of 620, if as much as 0″.3 apart. Stars of 5th magnitude and this distance could not be seen double owing to the increased amount of light. In connection with these observations Professor Keeler remarks: "Although the theoretical limit of resolution for a three-foot aperture is not reached in these observations, I do not think the mirror can do any better."

It is, however, in photographic work that the greatest field for the Crossley reflector appears to lie, and it is largely with respect to this line of work that any changes have been considered.

The ratio of aperture to focal length is so large in the instrument (a little greater than 1 to 6) that the field of view over which the star images are sufficiently free from distortion is only about 16′, or one inch, in diameter. The photographic equipment was designed to use plates $3\frac{1}{4}$x$4\frac{1}{4}$ inches in size. These are sufficiently large, for even with this size the star images show decided wings near the edges of the plates.

Several minor changes and improvements were made in the eye-end apparatus. Metal plate-holders were substituted for the wooden ones, as the latter could not be depended upon to keep their positions throughout the long exposures. Clamping screws were added to hold the plate-holder firmly in place. Spider threads were substituted for the coarse wires in the guiding eyepiece, and a system of mirrors added to illuminate the declination thread. A small electric lamp is used to illuminate the wires, current being supplied from the storage battery at the main observatory.

A piece of ruby glass between the lamp and wires prevents fogging of the plate.

As designed, the wires of the guiding eye-piece were in the same plane as the photographic plate, but as they were some three inches from the optical axis of the telescope a star's image was a crescent, and therefore unsuitable for purposes of accurate guiding. Outside this plane the star image, as seen in the guiding eye-piece, changes to an arrow-head whose point is directed to the optical axis of the telescope. As it was found that the focus of the telescope changed during long exposures, an image of the guiding star which was sensitive to changes of focus was highly desirable. Professor Keeler found that between the crescent and the arrow-head there was an image formed by the intersection, at an acute angle, of two well defined caustic curves in the aberration pattern. The intersection of these caustics offers a very satisfactory image on which to guide, and at the same time is very sensitive to changes of focus. The relation of the plane of the photographic plate and of the guiding threads was so altered that when the former was adjusted to accurate focus, by means of a high power positive eye-piece, a star's image assumed this particular form in the guiding eye-piece. By noting carefully at the commencement of the exposure the form of the star's image, the focus could be corrected by means of the focusing screw as changes were seen to occur. Photographs of four hours' duration were secured on which the star disks near the center of the plate were almost perfectly round, the smallest disks being from 2″ to 3″ in diameter.

In compensating for the variations of the motion of the telescope from that of the stars by moving the plate-holder, there is a limit which Professor Keeler has pointed out, to the amount which the plate-holder may be moved without causing distortions in some of the star images. This distortion arises from the fact that the motion of the plate-holder is in a straight line, while the stars describe small circles about the pole. Hence compensation by such a method of guiding is exact at the equator only. The amount which the plate-holder may be moved without causing an appreciable elongation of the star's image may be found from the formula,

$$d = \frac{e \cos \delta_1}{\cos \delta_2 - \cos \delta_1}$$

in which d is the displacement of the plate-holder; e the amount of elongation in the star's image which becomes perceptible; δ_1 the declination of the guiding star, and δ_2 the declination of the star on the plate farthest from the guiding star in declination. In the Crossley reflector it was found that at a declination of 70° (where many nebulæ were to be photographed) the plate-holder could not be moved in right ascension more than 1.0 mm. without causing an elongation of the fainter star images which were farthest from the guiding eye-piece in declination, of an amount equal to their own diameters. There is also a small distortion in declination, but on the scale of the Crossley photographs it is negligible.

To prevent halation in the long exposures, the plates are backed with a coating of Carbutt's 'Columbian Backing,' which has proved very satisfactory.

One of the earliest photographs obtained by Professor Keeler was a very successful one of the great nebula in Orion. This and similar photographs pointed to the great efficiency of the instrument for showing the structure in the nebulæ, and led to the systematic photographing of all the brighter ones within reach of the telescope. This program had been about half completed by Professor Keeler before his untimely death. In the prosecution of this work, great numbers of faint nebulæ were

revealed; on one plate no less than *thirty-one* new ones were found. The accurate positions of these new nebulæ are now being measured by Mr. Palmer. He finds, on the average, about *ten* new nebulæ to the plate.

Professor Keeler summarizes the conclusions to be drawn from the work so far accomplished as follows:

"1. Many thousands of unrecorded nebulæ exist in the sky. A conservative estimate places the number within reach of the Crossley reflector at about 120,000. The number of nebulæ in our catalogues is but a small fraction of this.

"2. These nebulæ exhibit all gradations of apparent size, from the great nebula in Andromeda down to an object which is hardly distinguishable from a faint star disk.

"3. Most of these nebulæ have a spiral structure.

"To these conclusions I may add another, of more restricted significance, though the evidence in favor of it is not yet complete. Among the objects which have been photographed with the Crossley telescope are most of the 'double' nebulæ figured in Sir John Herschel's catalogue (*Phil. Trans.*, 1833, Plate XV.). The actual nebulæ, as photographed, have almost no resemblance to the figures. They are, in fact, spirals, sometimes of very beautiful and complex structure; and, in any one of the nebulæ, the secondary nucleus of Herschel's figure is either a part of the spiral approaching the main nucleus in brightness, or it cannot be identified with any real part of the object. The significance of this somewhat destructive conclusion lies in the fact that these figures of Herschel have sometimes been regarded as furnishing analogies for the figures which Poincaré has deduced, from theoretical considerations, as being among the possible forms assumed by a rotating fluid mass; in other words, they have been regarded as illustrating an early stage in the development of double star systems. The actual conditions of motion in these particular nebulæ, as indicated by the photographs, are obviously very much more complicated than those considered in the theoretical discussion."

As evidence of the power of the Crossley telescope it may be noted that a very faint image of the Ring Nebula in Lyra was obtained with an exposure of thirty seconds; with an exposure of two minutes a well marked impression of the nebula is obtained and a surprisingly strong image of the central star, which is a very faint object visually in the 36-inch refractor.

In the course of the work on the nebulæ, two new asteroids have been discovered, by means of their trails, one at least of which was so faint as not to be seen with certainty with the large refractor. Observations of these asteroids were made photographically, and were found to compare very favorably in accuracy with such observations made visually with a large refractor. These results point to the great value of this instrument for finding and giving the positions of asteriods, whose places are approximately known.

One of the most promising fields for the Crossley reflector is undoubtedly that of stellar spectroscopy. Two spectrographs have been designed and built at the observatory. One is due to the generosity of Miss C. W. Bruce, and contains three prisms of 60° and one of 30°, with an aperture of two inches; the other has a single quartz prism and is intended to give measurable, though small, spectra of some special objects nearly at the limit of vision of the telescope.

From what has been said, it will be seen that a large amount of work of great importance has already been accomplished with the Crossley reflector, besides opening up new fields for future investigation.

Professor Keeler clearly recognized the

necessity for attention to the small details as an element of success. He says:

"The foregoing account of the small changes which have been made in the Crossley telescope and its accessories may appear to be unnecessarily detailed, yet these small changes have greatly increased the practical efficiency of the instrument, and therefore, small as they are, they are important. Particularly with an instrument of this character, the difference between poor and good results lies in the observance of just such small details as I have described."

C. D. Perrine.

Lick Observatory,
University of California,
September 23, 1900.

ADDRESS OF THE PRESIDENT OF THE CHEMICAL SECTION OF THE BRITISH ASSOCIATION.

THE MODERN SYSTEM OF TEACHING PRACTICAL INORGANIC CHEMISTRY AND ITS DEVELOPMENT.

In choosing for the subject of my Address to-day the development of the teaching of practical inorganic chemistry I do so, not only on account of the great importance of the subject, but also because it does not appear that this matter has been brought before this Section, in the President's Address at all events, during the last few years.

In dealing generally with the subject of the teaching of chemistry as a branch of science it may be well in the first place to consider the value of such teaching as a means of general education, and to turn our attention for a few minutes to the development of the teaching of science in schools.

There can be no doubt that there has been great progress in the teaching of science in schools during the last forty years, and this is very evident from the perusal of the essay, entitled 'Education: Intellectual, Moral, and Physical,' which Herbert Spencer wrote in 1859. After giving his reasons for considering the study of science of primary importance in education, Herbert Spencer continues: "While what we call civilization could never have arisen had it not been for science, science forms scarcely an appreciable element in our so-called civilized training."

From this it is apparent that science was not taught to any appreciable extent in schools at that date, though doubtless in some few schools occasional lectures were given on such scientific subjects as physiology, anatomy, astronomy and mechanics.

Herbert Spencer's pamphlet appears to have had only a very gradual effect towards the introduction of science into schemes of education. For many years chemical instruction was only given in schools at the schoolroom desk, or at the best from the lecture table, and many of the most modern of schools had no laboratories.

The first school to give any practical instruction in chemistry was apparently the City of London School, at which, in the year 1847, Mr. Hall was appointed teacher of chemistry, and there he continued to teach until 1869.* Besides the lecture theater and a room for storing apparatus, Mr. Hall's department contained a long room, or rather passage, leading into the lecture theater, and closed at each end with glass doors. In this room, which was fitted up as a laboratory, and used principally as a preparation room for the lectures, Mr. Hall performed experiments with the few boys who assisted him with his lectures. As accommodation was at that time strictly limited, he used to suggest simple experiments and

*Mr. A. T. Pollard, M.A., Head Master of the City of London School, has kindly instituted a search among the bound copies of the boys' terminal reports, and informs me that in the School form of Terminal Report a heading for Chemistry was introduced in the year 1847, the year of Mr. Hall's appointment.

encourage the boys to carry them out at home, and afterwards he himself would examine the substances they had made.

From this small beginning the teaching of chemistry in the City of London School rapidly developed, and this school now possesses laboratories which compare favorably with those of any school in the country.

The Manchester Grammar School appears to have been one of the first to teach practical chemistry. In connection with this school a small laboratory was built in 1868: this was replaced by a larger one in 1872, and the present large laboratories, under the charge of Mr. Francis Jones were opened in 1880.

Dr. Marshall Watts, who was the first science master in this school, taught practical chemistry along with the theoretical work from the commencement in 1868.

As laboratories were gradually multiplied it might be supposed that boys were given the opportunity to carry out experiments which had a close connection with their lecture-room courses. But the program of laboratory work which became all but universal was the preparation of a few gases, followed by the practice of qualitative analysis. The course adopted seems to have been largely built up on the best books of practical chemistry in use in the colleges at that time; but it was also, no doubt, largely influenced by the requirements of the syllabus of the Science and Art Department, which contained a scheme for teaching practical chemistry.* Even down to quite recent times it was in many schools still not considered essential that boys should have practical instruction in connection with lectures in chemistry.

A Report issued in 1897 by a special Committee appointed by the Technical Education Board of the London County Council adduces evidence of this from twenty-five secondary schools in London, in which there were 3,960 boys learning chemistry. Of these 1,698 boys, or 34 per cent., did no practical work whatever; 955 boys, or 24 per cent., did practical work, consisting of a certain amount of preparation of gases, together with qualitative analysis; but of these latter 743, or 77 per cent., had not reached the study of the metals in their theoretical work, so that their testing work can have been of little educational value. It was also found that in the case of 655, or 68 per cent. of the total number of boys taking practical work, the first introduction to practical chemistry was through qualitative analysis.

But some years before this Report was issued a movement had begun which was destined to have far-reaching effect. A Report 'on the best means for promoting scientific education in schools' having been presented to the Dundee Meeting of this Association in 1867, and published in 1868, a Committee of the British Association was appointed in 1887; 'for the purpose of inquiring and reporting upon the present methods of teaching chemistry.' The well-known Report which this Committee presented to the Newcastle meeting in 1889 insisted that it was worth while to teach chemistry in schools, not so much for the usefulness of the information imparted as for the special mental discipline it afforded if the scientific method of investigating nature were employed. It was argued that 'learners should be put in the attitude of discoverers, and led to make observations, experiments, and inferences for themselves.' And since there can be little progress without measurement, it was pointed out that the experimental work would necessarily be largely of a quantitative character.

* I find, on inquiry, that examinations in the Advanced Stage and Honors of Practical Chemistry were first held by the Science and Art Department in 1878, the practical examination being extended to the Elementary Stage in 1882.

Professor H. E. Armstrong, in a paper read at a conference at the Health Exhibition five years before this, had foreshadowed much that was in this Report. He also drew up a detailed scheme for 'a course of elementary instruction in physical science,' which was included in the Report of the Committee, and it cannot be doubted that this scheme and the labors of the Committee have had a very marked influence on the development of the teaching of practical chemistry in schools. That this influence has been great will be admitted when it is understood that schemes based on the recommendation of the Committee are now included in the codes for both Elementary Day Schools and Evening Continuation Schools. The recent syllabuses for elementary and advanced courses issued by the Incorporated Association of Headmasters and by the Oxford and Cambridge local board and others are evidently directly inspired by the ideas set forth by the Committee.

The department of Science and Art has also adopted some of the suggestions of the Committee, and a revised syllabus was issued by the Department in 1895, in which qualitative analysis is replaced by quantitative experiments of a simple form, and by other exercises so framed 'as to prevent answers being given by students who have obtained their information from books or oral instruction.' This was a very considerable advance, but it must be admitted that there is nothing in the syllabus which encourages, or even suggests, placing the learners in the attitude of discoverers, and this, in the opinion of the Committee of this Association, is vital if the teaching is to have educational value.

Many criticisms have been passed upon the 1889 Report. It has been said that life is much too short to allow of each individual advancing from the known to the unknown, according to scientific methods, and that even were this not so too severe a tax is made upon the powers of boys and girls. In answer to the second point it will be conceded that while it is doubtless futile to try to teach chemistry to young children, on the other hand experience has abundantly shown that the average schoolboy of fourteen or fifteen can, with much success, investigate such problems as were studied in the researches of Black and Scheele, of Priestley and Cavendish and Lavoisier, and it is quite remarkable with what interest such young students carry out this class of work.

It may be well to quote the words which Sir Michael Foster used in this connection in his admirable presidential address to this Association in 1899. He said: "The learner may be led to old truths, even the oldest, in more ways than one. He may be brought abruptly to a truth in its finished form, coming straight to it like a thief climbing over a wall; and the hurry and press of modern life tempt many to adopt this quicker way. Or he may be more slowly guided along the path by which the truth was reached by him who first laid hold of it. It is by this latter way of learning the truth, and by this alone, that the learner may hope to catch something at least of the spirit of the scientific inquirer."

I believe that in the determination of a suitable school course in experimental science this principle of historical development is a very valuable guide, although it is not laid down in the 1889 Report of the British Association.

The application of this principle will lead to the study of the solvent action of water, of crystallization, and of the separation of mixtures, of solids before the investigation of the composition of water, and also before the investigation of the phenomena of combustion. It will lead to the investigation of hydrochloric acid before chlorine, and especially to the postponement of atomic and molecular theories, chemical

equations, and the laws of chemical combination, until the student has really sufficient knowledge to understand how these theories came to be necessary.

There can be no doubt that this new system of teaching chemistry in schools has been most successful. Teachers are delighted with the results which have already been obtained, and those whom I have had the opportunity of consulting, directly and indirectly, cannot speak too highly of their satisfaction at the disappearance of the old system of qualitative analysis, and the institution of the new order of things. Especially I may mention in this connection the excellent work which is being carried on under the supervision of Dr. Bevan Lean at the Friends' School in Ackworth, where the boys have attained results which are far in advance of anything which would have been thought possible a few years since.

It is, of course, obvious that if a schoolboy is made to take the attitude of a discoverer his progress may appear to be slow. But does this matter? Most boys will not become professional chemists; but if while at school a boy learns how to learn, and how to 'make knowledge'* by working out for himself a few problems, a habit of mind will be formed which will enable him in future years to look in a scientific spirit at any new problems which may face him. When school days are past the details of the preparation of hydrogen may have been forgotten; but it was really understood at the time that it could not be decided at once whether the gas was derived from the acid or from the metal, or from the water, or in part from the one and in part from the other, an attitude of scepticism and of suspended judgment will have been formed, which will continue to guard from error.

* *Cf.* Professor J. G. Macgregor in *Nature*, September, 1899.

In the new system of teaching chemistry in schools much attention must necessarily be given to weights and measurements; indeed, the work must be largely of a quantitative kind, and it is in this connection that an important note of warning has been sounded by several teachers.* They consider, very rightly, that it is important to point out clearly to the scholar that science does not consist of measurement, but that measurement is only a tool in the hand of the inquirer, and that when once sufficient skill has been developed in its use it should be employed only with a distinct object. Measurements should, in fact, be made only in reference to some actual problem which appears to be really worth solving, not in the accumulation of aimless details.

And, of course, all research carried out must be genuine and not sham, and all assumption of the 'obvious' must be most carefully guarded against. But the young scholar must, at the same time, not forget that although the scientific method is necessary to enable him to arrive at a result, in real life it is the answer to the problem which is of the most importance. †

Although, then, there has been so much discussion, during the last ten years, on the subject of teaching chemistry in schools, and such steady progress has been made towards devising a really satisfactory system of teaching the subject to young boys and girls, it is certainly very remarkable that practically nothing has been said or written bearing on the training which a student who wishes to become a chemist is to undertake at the close of his school-days at the college or university in which his education is continued.

One of the most remarkable points, to my mind, in connection with the teaching of

* *Cf.* H. Picton in *The School World*, November, 1899; Bevan Lean, *ibid.*, February, 1890.

† *Cf.* Mrs. Bryant, *Special Reports on Educational Subjects*, Vol. II., p. 113.

chemistry is the fact that although the science has been advancing year by year with such unexampled rapidity, the course of training which the student goes through during his first two years at most colleges is still practically the same as it was thirty or forty years ago. Then, as now, after preparing a few of the principal gases, the student devotes the bulk of his first year to qualitative analysis in the dry and wet way, and his second year to quantitative analysis, and, although the methods employed in teaching the latter may possibly have undergone some slight modification, there is certainly no great difference between the routine of simple salt and mixture followed by quantitative analysis practiced at the present day and that which was in vogue in the days of our fathers and grandfathers.

Since, then, the present system has held the field for so long, not only in this country but also on the Continent, it is worth while considering whether it affords the best training which a student who wishes to become a chemist can undergo in the short time during which he can attend at a college or university. In considering this matter I was led in the first place to carefully examine old books and other records, with the object of finding out how the present system originated, and I think that valuable and interesting information bearing on the subject may be obtained from a very brief sketch of the rise and development of the present system of teaching chemistry, and especially in so far as it bears on the inclusion of qualitative analysis. Unfortunately, it is not so easy to gain a good historical acquaintance with the matter as I first imagined would be the case, and this is due in a large measure to the fact that so few of the laboratories which took an active part in the development of the present system of chemical training have left any record of the methods which they employed. In this connection I may, perhaps, be allowed to suggest that it would be a valuable help to the future historian if all prominent teachers of chemistry would leave behind them a brief record of the system of teaching adopted in their laboratories, showing the changes which they had instituted, the object of these changes and the results which followed their adoption.

There is no doubt that the progress of practical chemistry went largely hand in hand with the progress of theoretical chemistry, for as the latter gradually developed, so the necessity for the determination of the composition, first of the best known, and then of the rarer minerals and other substances, became more and more marked.

The analytical examination of substances in the dry way was employed in very early times in connection with metallurgical operations, and especially in the determination of the presence of valuable constituents in samples of minerals. Cupellation was used by the Greeks in the separation of gold and silver from their ores and in the purification of these metals. Geber knew that the addition of niter to the ore facilitated the separation of gold and silver, and subsequently Glauber (1604–1668) called attention to the fact that many commoner metals could easily be separated from their ores with the aid of niter.

But it was not till the eighteenth century that any marked progress was made in analysis in the dry way, and the progress which then became rapid was undoubtedly due to the discovery of the blowpipe, and to the introduction of its use into analytical operations. The blowpipe is mentioned for the first time in 1660, in the transactions of the Accademia del Cimento of Florence, but the first to recommend its use in chemical operations was Johann Andreas Cramer in 1739. The progress of blowpipe analysis was largely due to Gahn (1745–1818), who spent much time in perfecting its use in the

examination of minerals, and it was he who first used platinum wire and cobalt solution in connection with blowpipe analysis. The methods employed by Gahn were further developed by his friend Berzelius (1779–1848), who gave much attention to the matter, and who with great skill and patience gradually worked out a complete scheme of blowpipe analysis, and published it in a pamphlet, entitled 'Ueber die Anwendung des Löthrohrs,' which appeared in 1820. After the publication of this work blowpipe analysis rapidly came into general use in England, France and Germany, and the scheme devised by Berzelius is essentially that employed at the present day.

Indeed, the only notable additions to the method of analysis in the dry way since the time of Berzelius are the development of flame reactions, which Bunsen worked out with such characteristic skill and ingenuity, and the introduction of the spectroscope.

The necessity for some process other than that of analysis in the dry way seems, in the first instance, to have arisen in quite early times in connection with the examination of drugs, not only on account of the necessity for discovering their constituents, but also as a means of determining whether they were adulterated. In such cases analysis in the dry way was obviously unsuitable, and experience soon showed that the only way to arrive at the desired result was to treat the substance under examination with aqueous solutions of definite substances, the first reagent apparently being a decoction of gallnuts, which is described by Pliny as being employed in detecting adulteration with green vitriol.

The progress made in connection with wet analysis was, however, exceedingly slow, largely owing to the lack of reagents; but as these were gradually discovered wet analysis rapidly developed, especially in the hands of Tachenius, Scheele, Boyle, Hoffman, Margraf and Bergmann. Boyle (1626–1691) especially had an extensive knowledge of reagents and their application; and, indeed, it was Boyle who first introduced the word 'analysis' for those operations by which substances may be recognized in the presence of one another. Boyle knew how to test for silver with hydrochloric acid, for calcium salts with sulphuric acid, and for copper by the blue solution produced by ammonia.

Margraf (1709–1782) introduced prussiate of potash for the detection of iron, and Bergmann (1735–1784) not only introduced new reagents and new methods for decomposing minerals and refractory substances, such as fusion with potash, digestion with nitric acid or hydrochloric acid, but he also was the first to suggest the application of tests in a systematic way, and, indeed, the method of analysis which he developed is on much the same lines as that in use at the present day. He paid special attention to the qualitative analysis of minerals, and gave careful instructions for the analysis of gold, platinum, silver, lead, copper, zinc and other ores. The work of Scheele (1742–1786) had indirectly a great influence on qualitative analysis, as, although he did not give a general systematic method of procedure in the analysis of substances of unknown composition, yet the methods which he employed in the examination of new substances were so original and exact as to remain models of how qualitative analysis shall be conducted.

Great strides in analytical chemistry in the wet way were made through the work of Berzelius, who, by the discovery of new methods, such as the decomposition of silicates by hydrofluoric acid and the introduction of new tests, greatly advanced the art. He paid special attention to perfecting the methods of analysis of mineral waters, and these researches as well as his work on ores, and particularly his investigation of platinum ores, stamp Berzelius as one of

the great pioneers in qualitative and quantitative analytical chemistry.

By the labors of the great experimenters whom I have mentioned qualitative analysis gradually acquired the familiar appearance of to-day, and many books were written with the object of arranging the mass of information which had accumulated, and of thus rendering it available for the student in his efforts to investigate the composition of new minerals and other substances. Among these books may be mentioned the 'Handbuch der analytischen Chemie,' by H. Rose, and especially the well-known analytical text-books of Fresenius, which have had an extraordinarily wide circulation and passed through many editions.

The work of the great pioneers in analytical chemistry was work done often under circumstances of great difficulty, as before the end of the seventeenth century there were no public institutions of any sort in which a practical knowledge of chemistry could be acquired. Lectures were, of course, given from very early times, but it was not until the time of Guillaume François Rouelle (1703–1770), at the beginning of the eighteenth century, that lectures began to be illustrated by experiments. Rouelle, who was very active as a teacher, numbered among his pupils many men of eminence, such as Lavoisier and Proust, and it was largely owing to his influence that France took such a lead in practical teaching. In Germany progress was much slower, and in our country the introduction of lectures illustrated by experiments seems to have been mainly due to Davy.

When it is considered how slowly experimental work came to be recognized as a means of illustration and education, even in connection with lectures, it is not surprising that in early times practical teaching in laboratories should have been thought quite unnecessary.

The few laboratories which existed in the sixteenth century were built mainly for the practice of alchemy by the reigning princes of the time, and, indeed, up to the beginning of the nineteenth century, the private laboratories of the great masters were the only schools in which a favored few might study, but which were not open to the public. Thus we find that Berzelius received in his laboratory a limited number of students who worked mostly at research: these were not usually young men, and his school cannot thus be considered as a teaching institution in the ordinary sense of the word.

The earliest laboratory open for general instruction in Great Britain was that of Thomas Thomson, who after graduating in Edinburgh in 1799, began lecturing in that city in 1800, and opened a laboratory for the practical instruction of his pupils. Thomson was appointed lecturer in Chemistry in Glasgow University in 1807, and Regius Professor in 1818, and in Glasgow he also opened a general laboratory.

The first really great advance in laboratory teaching is due to Liebig, who, after working for some years in Paris under Gay-Lussac, was appointed in 1824 to be Professor of Chemistry in Giessen. Liebig was strongly impressed with the necessity for public institutions where any student could study chemistry, and to him fell the honor of founding the world-famed Giessen Laboratory, the first public institution in Germany which brought practical chemistry within the reach of all students.

Giessen rapidly became the center of chemical interest in Germany, and students flocked to the laboratory in such numbers as to necessitate the development of a systematic course of practical chemistry, and in this way a scheme of teaching was devised which, as we shall see later, has served as the foundation for the system of practical chemistry in use at the present day.

When the success of this laboratory had been clearly established many other towns discovered the necessity for similar institutions, and in a comparatively short time every university in Germany possessed a chemical laboratory. The teaching of practical chemistry in other countries was, however, of very slow growth; in France, for example, Wurtz in 1869 drew attention to the fact that there was at that time only one laboratory which could compare with the German laboratories, namely, that of the École Normale Supérieure.

In this country the provision of suitable laboratories for the study of chemistry seems to date from the year 1845, when the College of Chemistry was founded in London, an institution which under A. W. Hofmann's guidance rapidly rose to such a prominent position.

In 1851 Frankland was appointed to the chair of chemistry in the new college founded in Manchester by the trustees of John Owens, and here he equipped a laboratory for the teaching of practical chemistry. Under Sir Henry Roscoe this laboratory soon became too small for the growing number of chemical students, a defect which was removed when the new buildings of the college were opened in 1873. In 1849 Alexander Williamson was appointed Professor of Practical Chemistry at University College, London, where he introduced the practical methods of Liebig.

Following these examples, the older universities gradually came to see the necessity for providing accommodation for the practical teaching of chemistry, with the result that well-equipped laboratories have been erected in all the centers of learning in this country.

Since Liebig, by the establishment of the Giessen Laboratory, must be looked upon as the pioneer in the development of practical laboratory teaching, it will be interesting to endeavor to obtain some idea of the methods which he used in the training of the students who attended his laboratory in Giessen. From small beginnings he gradually introduced a systematic course of practical chemistry, and a careful comparison shows that this was similar in many ways to that in use at the present day. The student at Giessen, after preparing the more important gases, was carefully trained in qualitative and quantitative analysis; he was then required to make a large number of preparations, after which he engaged in original research.

Although there is, as far as I have been able to ascertain, no printed record of the nature of the quantitative work and the preparations which Liebig required from his students, the course of qualitative analysis is easily followed, owing to the existence of a most interesting book published for the use of the Giessen students.

In 1846, at Liebig's request, Henry Will, Ph.D., Extraordinary Professor of Chemistry in the University of Giessen, wrote a small book, for use at Giessen, called 'Giessen Outlines of Analysis,' which shows clearly the kind of instruction given in that laboratory at the time in so far as qualitative analysis is concerned. This book, which contains a preface by Liebig, is particularly interesting on account of the fact that it is evidently the first Introduction to Analysis intended for the training of elementary students which was ever published. In the preface Liebig writes: "The want of an introduction to chemical analysis adapted for the use of a laboratory has given rise to the present work, which contains an accurate description of the course I have followed in my laboratory with great advantage for twenty-five years. It has been prepared at my request by Professor Will, who has been my assistant during a great part of this period."

This book undoubtedly had a considerable circulation, and was used in most of

the laboratories which were in existence at that time, and thus we find, for example, that the English translation which Liebig 'hopes and believes will be acceptable to the English public' was the book used by Hofmann for his students at the College of Chemistry. In this book the metals are first divided into groups much in the same way as is done now; each group is then separately dealt with, the principal characteristics of the metals of the group are noted, and their reactions studied. Those tests which are useful in the detection of each metal are particularly emphasized, and the reasons given for selecting certain of them as of special value for the purposes of separating one metal from another.

Throughout this section of the book there are frequent discussions as to the possible methods of the separation, not only of the metals of one group, but of those belonging to different groups; and the whole subject is treated in a manner which shows clearly that Liebig's great object was to make the student think for himself. After studying in a similar manner the behavior of the principal acids with reagents, the student is introduced to a course of qualitative analysis comprising, 1, preliminary examination of solids; 2, qualitative analysis of the substance in solution.

Both sections are evidently written with the object, not only of constructing a system of qualitative analysis, but more particularly of clearly leading the student to argue out for himself the methods of separation which he will ultimately adopt. The book concludes with a few tables which differ considerably in design from those in use at the present day, and which are so meager that the student could not possibly have used them mechanically.

The system introduced in this book, no doubt owing to the excellent results obtained by its use, was rapidly recognized as the standard method of teaching analysis in most of the institutions existing at that time. Soon the course began to be further developed, book after book was published on the subject, and gradually the teaching of qualitative analysis assumed the shape and form with which we are all so well acquainted. But the present-day book on qualitative analysis differs widely from 'Giessen Outlines' in this respect, that whereas in the latter the tables introduced are mere indications of the methods of separation to be employed, and are of such a nature that the student who did not think for himself must have been constantly in difficulties, in the book of the present day these tables have been worked out to the minutest detail. Every contingency is provided for; nothing is left to the originality of the student; and that which, no doubt, was once an excellent course has now become so hopelessly mechanical as to make it doubtful whether it retains anything of its former educational value.

The question which I now wish to consider more particularly is whether the system of training chemists which is at present adopted, with little variation, in our colleges and universities is a really satisfactory one, and whether it supplies the student with the kind of knowledge which will be of the most value to him in his future career.

Those who study chemistry may be roughly divided as to their future careers into two groups—those who become teachers and those who become technical chemists. Now, whether the student takes up either the one or the other career, I think that it is clear that the objects to be aimed at in training him are to give him a sound knowledge of his subject, and especially to so arrange his studies as to bring out in every possible way his capacity for original thought.

A teacher who has no originality will hardly be successful, even though he may

possess a very wide knowledge of what has already been done in the past. He will have little enthusiasm for his subject, and will continue to teach on the lines laid down by the text-books of the day, without himself materially improving the existing methods, and, above all, he will be unable, and will have no desire, to add to our store of knowledge by original investigation.

It is in the power of almost every teacher to do some research work, and it seems probable that the reason why more is not done by teachers is because the importance of research work was not sufficiently insisted on, and their original faculty was not sufficiently trained, at the schools and colleges where they received their education.

And these remarks apply with equal force to the student who subsequently becomes a technical chemist.

In the chemical works of to-day sound knowledge is essential, but originality is an even more important matter. A technical chemist without originality can scarcely rise to a responsible position in a large works, whereas a chemist who is capable of constantly improving the process in operation, and of adding new methods to those in use, becomes so valuable that he can command his own terms.

Now, this being so, I think it is extraordinary that so many of the students who go through the prescribed course of training—say for the Bachelor of Science degree—not only show no originality themselves, but seem also to have no desire at the conclusion of their studies to engage in original investigation under the supervision of the teacher. That this is so is certainly my experience as a teacher examiner, and I feel sure that many other teachers will endorse this view of the case.

If we inquire into the reason for this deficiency in originality we shall, I think, be forced to conclude that it is in a large measure due to the conditions of study and the nature of the courses through which the student is obliged to pass.

A well-devised system of quantitative analysis is undoubtedly valuable in teaching the student accurate manipulation, but it has always seemed to me that the long course of qualitative analysis which is usually considered necessary, and which generally precedes the quantitative work, is not the most satisfactory training for a student.

There can be no doubt that to many students qualitative analysis is little more than a mechanical exercise: the tables of separation are learnt by heart, and every substance is treated in precisely the same manner: such a course is surely not calculated to develop any original faculty which the student may possess. Then, again, when the student passes on to quantitative analysis, he receives elaborate instructions as to the little details he must observe in order to get an accurate result; and even after he has become familiar with the simpler determinations he rarely attempts, and indeed has no time to attempt, anything of the nature of an original investigation in qualitative or quantitative analysis. It indeed sometimes happens that a student at the end of his second year has never prepared a pure substance, and is often utterly ignorant of the methods employed in the separation of substances by crystallization; he has never conducted a distillation, and has no idea how to investigate the nature and amounts of substances formed in chemical reactions; practically all his time has been taken up with analysis. That this is not the way to teach chemistry was certainly the opinion of Liebig, and in support of this I quote a paragraph bearing on the subject which occurs in a very interesting book on 'Justus von Liebig: his Life and Work,' written by W. A. Shenstone (pp. 175, 176).

"In his practical teaching Liebig laid

great stress on the producing of chemical preparations; on the students preparing, that is to say, pure substances in good quantity from crude materials. The importance of this was, even in Liebig's time, often overlooked; and it was, he tells us, more common to find a man who could make a good analysis than to find one who could produce a pure preparation in the most judicious way.

"There is no better way of making one's self acquainted with the properties of a substance than by first producing it from the raw material, then converting it into its compounds, and so becoming acquainted with them. By the study of ordinary analysis one does not learn how to use the important methods of crystallization, fractional distillation, nor acquire any considerable experience in the proper use of solvents. In short, one does not, as Liebig said, become a chemist."

One reason why the present system of training chemists has persisted so long is no doubt because it is a very convenient system: it is easily taught, does not require expensive apparatus, and, above all, it lends itself admirably for the purpose of competitive examination.

The system of examination which has been developed during the last twenty years has done much harm, and is a source of great difficulty to any conscientious teacher who is possessed of originality, and is desirous, particularly in special cases, of leaving the beaten track.

In our colleges and universities most of the students work for some definite examination—frequently for the Bachelor of Science degree—either at their own University or at the University of London.

For such degrees a perfectly definite course is prescribed and must be followed, because the questions which the candidate will have to answer at his examination are based on a syllabus which is either published or is known by precedent to be required. The course which the teacher is obliged to teach is thus placed beyond his individual power of alteration, except in minor details, and originality in the teacher is thereby discouraged: he knows that all students must face the same examination, and he must urge the backward man through exactly the same course as his more talented neighbor.

In almost all examinations salts or mixtures of salts are given for qualitative analysis. 'Determine the constituents of the simple salt A and of the mixture B' is a favorite examination formula; and as some practical work of this sort is sure to be set, the teacher knows that he must contrive to get one and all of his students into a condition to enable them to answer such questions.

If, then, one considers the great amount of work which is required from the present-day student, it is not surprising that every aid to rapid preparation for examination should be accepted with delight by the teacher; and thus it comes about that tables are elaborated in every detail, not only for qualitative analysis in inorganic chemistry, but, what is far worse, for the detection of some arbitrary selection of organic substances which may be set in the syllabus for the examination. I question whether any really competent teacher will be found to recommend this system as one of educational value or calculated to bring out and train the faculty of original thought in students.

If, then, the present system is so unsatisfactory, it will naturally be asked, how are students to be trained, and how are they to be examined so as to find out the extent of the knowledge of their subject which they have acquired?

In dealing with the first part of the question—that is, the training best suited to chemists—I can, of course, only give my

own views on the subject—views which, no doubt, may differ much from those of many of the teachers present at this meeting. The objects to be attained are, in my opinion, to give the student a sufficient knowledge of the broad facts of chemistry, and at the same time so to arrange his practical work in particular as to always have in view the training of his faculty of original thought.

I think it will be conceded that any student, if he is to make his mark in chemistry by original work, must ultimately specialize in some branch of the subject. It may be possible for some great minds to do valuable original work in more than one branch of chemistry, but these are the exceptions; and as time goes on, and the mass of facts accumulates, this will become more and more impossible. Now a student at the commencement of his career rarely knows which branch of the subject will fascinate him most, and I think, therefore, that it is necessary, in the first place, to do all that is possible to give him a thorough grounding in all branches of the subject. In my opinion the student is taken over too much ground in the lecture courses of the present day: in inorganic chemistry, for example, the study of the rare metals and their reactions might be dispensed with, as well as many of the more difficult chapters of physical chemistry, and in organic chemistry such complicated problems as the constitutions of uric acid and the members of the camphor and terpene series, etc., might well be left out. As matters stand now, instruction must be given on these subjects simply because questions bearing on them will probably be asked at the examination.

And here perhaps I might make a confession, in which I do not ask my fellow-teachers to join me. My name is often attached to chemistry papers which I should be sorry to have to answer; and it seems to me the standard of examination papers, and especially of Honors examination papers, is far too high. Should we demand a pitch of knowledge which our own experience tells us can not be maintained for long?

In dealing with the question of teaching practical chemistry it may be hoped, in the first place, that in the near future a sound training will be given in elementary science in most schools, very much on the lines which I mentioned in the first part of this address. The student will then be in a fit state to undergo a thoroughly satisfactory course of training in inorganic chemistry during his first two years at college. Without wishing in any way to map out a definite course, I may be allowed to suggest that instead of much of the usual qualitative and quantitative analysis, practical exercises similar to the following will be found to be of much greater educational value.

(1) The careful experimental demonstration of the fundamental laws of chemistry and physical chemistry.

(2) The preparation of a series of compounds of the more important metals, either from their more common ores or from the metals themselves. With the aid of the compounds thus prepared the reactions of the metals might be studied and the similarities and differences between the different metals then carefully noted.

(3) A course in which the student should investigate in certain selected cases: (*a*) the conditions under which action takes place; (*b*) the nature of the products formed; (*c*) the yield obtained. If he were then to proceed to prepare each product in a state of purity, he would be doing a series of exercises of the highest educational value.

(4) The determination of the combining weights of some of the more important metals. This is in most cases comparatively simple, as the determination of the combining weights of selected metals can be very accurately carried out by measuring

the hydrogen evolved when an acid acts upon them.

Many other exercises of a similar nature will readily suggest themselves, and in arranging the course every effort should be made to induce the student to consult original papers and to avoid as far as possible any tendency to mere mechanical work.

The exact nature of such a course must, however, necessarily be left very much in the hands of the teacher, and the details will no doubt require much consideration; but I feel sure that a course of practical inorganic chemistry, could be constructed which, while teaching all the important facts which it is necessary for the student to know, will, at the same time, constantly tend to develop his faculty of original thought.

Supposing such a course were adopted (and the experiment is well worth trying), there still remains the problem of how the student who has had this kind of training is to be examined.

With regard to his theoretical work there would be no difficulty, as the examination could be conducted on much the same lines as at the present time. In the case of the practical examination I have long felt that the only satisfactory method of arriving at the value of a student's practical knowledge is by the inspection of the work which he has done during the whole of his course of study, and not by depending on the results of one or two days' set examination. I think that most examiners will agree with me that the present system of examination in practical chemistry is highly unsatisfactory. This is perhaps not so apparent in the case of the qualitative analysis of the usual simple salt or mixture; but when the student has to do a quantitative exercise, or when a problem is set, the results sent in are frequently no indication of the value of the student's practical work. Leaving out of the question the possibility of the student being in indifferent health during the short period of the practical examination, it not infrequently happens that he, in his excitement, has the misfortune to upset a beaker when his quantitative determination is nearly finished, and as a result he loses far more marks than he should do for so simple an accident.

Again, in attacking a problem he has usually only time to try one method of solution, and if this does not yield satisfactory results he again loses marks; whereas in the ordinary course of his practical work, if he were to find that the first method was faulty he would try other methods until he ultimately arrived at the desired result.

It is difficult to see why such an unsatisfactory system as this might not be replaced by one of inspection, which I think could easily be so arranged as to work well.

A student taking, say, a three years' course for the degree of Bachelor of Science might be required to keep very careful notes of all the practical work which he does during this course, and in order to avoid fraud his notebook could from time to time be initialed by the professor or demonstrator in charge of the laboratory. An inspection of these notebooks could then be made at suitable times by the examiners for the degree, by which means a very good idea would be obtained of the scope of the work which the student had been engaged in, and if thought necessary a few questions could easily be asked in regard to the work so presented. Should the examiners wish to further test the candidate by giving him an examination, I submit that it would be much better to set him some exercise of the nature of a simple original investigation, and to allow him two or three weeks to carry this out, than to depend on the hurried work of two or three days.

The object which I had in view in writing this address was to call attention to the fact that our present system of training in

chemistry does not appear to develop in the student the power of conducting original research, and at the same time to endeavor to suggest some means by which a more satisfactory state of things might be brought about. I have not been able, within the limits of this address, to consider the conditions of study during the third year of the student's career at college, or to discuss the increasing necessity for extending that course and insisting on the student carrying out an adequate original investigation before granting him a degree, but I hope on some future occasion to have the opportunity of returning to this very important part of the subject. If any of the suggestions I have made should prove to be of practical value and should lead to the production of more original research by our students, I shall feel that a useful purpose has been served by bringing this matter before this Section. In concluding I wish to thank Professor H. B. Dixon, Professor F. S. Kipping, and others, for many valuable suggestions, and my thanks are especially due to Dr. Bevan Lean for much information which he gave me in connection with that part of this address which deals with the teaching of chemistry in schools.

W. H. PERKIN.

SCIENTIFIC BOOKS.

La face de la terre. By EDOUARD SUESS. Translated from the German *Das Antlitz der Erde*, by EMMANUEL DE MARGERIE and others. Vol. II. Paris, Armand Colin & Cie., 1900. Pp. 878.

The first volume of this important translation has already been noticed in the pages of SCIENCE (Vol. VII., p. 803). The second volume contains the third part of the work dealing with 'The Seas.' After a brief review of the opinion of geographers concerning the question of changes of level of the sea in relation to the land, Suess adopts a terminology intended to avoid any implication of the movement of the land in relation to the sea in observed displacement of shore-lines. These 'shifts of relative level,' as Robert Chambers termed them, are then qualified as *negative* when the sea-level appears to fall and positive when it appears to rise, in accordance with the terminology employed in reading tide-gauges. For the expression 'elevation of the continent,' we may substitute then 'negative displacement of the shore-line,' and for 'submergence of the continent,' positive displacement.

The geological structure of the lands about the Atlantic is treated with much care in order to bring out the history of displacements of shore-line in this part of the world. A similar discussion is devoted to the contours of the Pacific Ocean. In summarizing the characters of these two great ocean basins, Suess finds that "with the exception of the Cordillera of the Antilles and of the mountainous trunk of Gibraltar which circumscribes the two Mediterraneans, no part of the contours of the Atlantic Ocean is determined by a folded chain. The internal border with groups of folds, the coasts cut by rias indicating a sinking of chains, the inclined fractures of horsts and the step-faults—such are the varied elements which determine the plan of the shores of the Atlantic Ocean."

As for the Pacific Ocean, "with the exception of a segment of the coast of Central America in Guatemala where the Cordillera making the turn of the Antilles is depressed, all parts of the border of the Pacific Ocean, of which the geology is known, are formed by chains of mountains folded towards the ocean in such a way that their external plications serve to outline the continent itself or constitute a belt of peninsulas and aligned islands." He then considers the ancient Paleozoic seas with the view of sifting the evidence which their sediments and faunas present in relation to the question of 'submergence and emergence of lands' and 'movements of the hydrosphere.' Our author finds insuperable difficulties in the commonly accepted explanation, and in this and following sections of the work develops the idea of swayings of the ocean waters alternately towards the equator and the poles to account for the numerous instances of advance and retreat of the sea afforded by the Paleozoic and Mesozoic for-

mations of the existing continents. Mesozoic and Tertiary geology are treated in the same comprehensive way, in the endeavor to show the former relations of sea-level to the lands.

In the last chapter of this volume, Suess gives the principal points in his theory. "Once," he states, "that the marine depressions are regarded as sunken tracts, the continents acquire the character of horsts, and the pointed form directed towards the south, in the case of Africa, India and Greenland, is explained by the intersection of fields of sinking of which the principal domain is found in the south.

"The crust of the earth sinks; the sea follows it. But inasmuch as the sinkings of the lithosphere are limited in extent, the lowering of the surface of the sea affects the entire perimeter of the oceanic areas; it produces a general negative movement.

"The formation of sediments causes a positive uninterrupted eustatic displacement of the shore-lines." Other causes, such as variation in the quantity of water in the seas dependent upon the rate of formation of silicates and upon the variable action of volcanoes, give rise also to eustatic movements of the ocean. These changes with the movements of the ocean above noted form the outlines of his theory.

Suess appears to be placed in the necessity of minimizing the changes of level which many geologists have postulated in recent geologic time, for these supposed changes exceed the effects attributable to the operations which he invokes. Thus, to take but one example of evidence adduced in favor of profound alteration of level—that of the so-called submarine gorges of the Hudson, the Congo, and other rivers, Suess contends with Forel and others that these channels are the result of excavation and deposition now going on as in Lake Geneva. In this view such cañons are not criteria of change of level. To this criticism of the doctrine of extreme changes of recent level may be added that made by Davis upon the interpretation of fjords in high glaciated latitudes, that the ice has excavated the deep fjords and that their depth below sea level is not necessarily a measure of depression of the land (Proc. Boston Soc. Nat. His., Vol. XXIX. 227–322. 1900). So also the high terraces reported in the far north are not without close scrutiny to be taken as evidence of elevation since there are diverse kinds of terraces, some of them built in ice-confined waters far above sea-level.

It is understood that the venerable author of *Das Antlitz der Erde* has in preparation a concluding section of his great work. In that we may expect to find the discussion of many questions, which his singularly attractive hypothesis of a swinging, rising and falling ocean raises, in the light of the work of Lord Kelvin and other physico-geologists upon the rate of contraction of the earth and upon the apparent tilting of a continent with its Great Lakes, as in the case of North America.

The two volumes of the new French edition form perhaps the best summary extant of the geology of the globe and should find an English translator.

J. B. WOODWORTH.

Mesures électrique; essais laboratoire. By E. VIGNERON and P. LETHEULE. Paris, Gauthier Villars. (No date.)

Resistance électrique et fluidité. By GOURÉ DE VILLEMONTEÉ, Paris. Gauthier-Villars. (No date.)

These two small octavo volumes, of one hundred and eighty and one hundred and eighty-seven pages respectively, are installments of the *Encyclopédie scientifique des aide-mémoire.*

The first contains a good discussion of the methods for measuring electric current, electromotive force, resistance, electrostatic capacity and self-induction.

The second is a very complete résumé of the experimental work that has been done in the attempt to discover the relationship between the electrical resistance of electrolytes and their viscosity.

Vigneron and Letheule devote eight introductory pages to *généralités sur les grandeurs.* They say that "une grandeur est dite mesurable quand on peut la comparer à une grandeur de même espèce et que le résultat de la comparaison donne à notre esprit une satisfaction complète." This statement is, indeed, somewhat

cleared up by subsequent statements given by the authors, but on the whole the introduction seems very unsatisfactory.

Length, angle, mass and time are called measurable quantities because these attributes (to speak of them briefly) may be divided into parts, which by means of one or another kind of congruence, are judged to be equal or like parts, and these parts may then be counted. This fundamental notion which is due, we believe, to Helmholtz, is no doubt the real basis of quantitative relations in physics; and it should be remembered that, although we frequently speak of the measurement of an electric current, of a magnetic field and what not, we never do actually measure anything but lengths, angles, masses and time intervals.

In the first chapter, on electrical units and quantities, Vigneron and Letheule make a distinction between *electromotive force* and *potential difference*, which distinction, being largely in vogue among electricians and not being based upon the fundamental conception of potential, it is a disservice to perpetuate. A distinction, however, there certainly is between the two, and it is, according to Maxwell, as follows:

When electric charge is transferred from one point to another work is usually done. The amount of work done depends in general upon the path along which the charge is carried. The work done in carrying unit charge along a given path is called the *electromotive force* along that path.

In special cases the electromotive force is the same along any two coterminus paths. In such a case the common value of the electromotive force is called the *potential difference* between the terminal points.

Now it seems to us that no author should attempt to make any other distinction between electromotive force and potential difference than the above. In particular the distinction between the *total electromotive* force of an electric generator and the *electromotive force between the terminals of the generator* should not be confused with the distinction between electromotive force and potential difference. One may answer, indeed, that the practical electrician is concerned with the distinction between *total* and *external* electromotive forces of electric generators, and not at all concerned with the fine distinction, according to Maxwell, between electromotive force and potential difference. This is too true, but this is no reason why electricians should be permitted to misuse these terms without protest, for very certainly the distinction between total and external electromotive force of a generator has nothing essentially in common with the distinction between electromotive force and potential difference in the sense in which Maxwell uses these terms.

There is one thing in which we know of only one person (Heaviside) who agrees with us, namely, that the notion of electric potential might best be dropped in the subject of electrodynamics, and we are convinced that the preference of most electricians for the term *potential* to the term *electromotive force* is in their tongues, not in their heads.

W. S. FRANKLIN.

BOOKS RECEIVED.

Text-book of Physiology. Edited by E. A. SCHÄFER. Edinburgh and London, Young J. Pentland. New York, The Macmillan Company. 1900. Vol. II., pp. xxiv + 1365. $10.00.

The Theory and Practice of Hygiene. J. LANE NOTTER and W. H. HORROCKS. Philadelphia, P. Blakiston's Sons & Co. 1900. Second Edition. Pp. xvii + 1085. $7.00.

A Treatise on Zoology. Edited by E. RAY LANKESTER. Part II., *The Porifera and Cœlentera.* E. A. MINCHIN, G. HERBERT FOWLER and GILBERT C. BOURNE. London, Adam and Charles Black. New York, The Macmillan Company. 1900. $5.50.

Free-hand Perspective. VICTOR T. WILSON. New York, John Wiley & Sons. London, Chapman & Hall, Limited. 1900. Pp. xii + 268. $2.50.

Dynamo Electric Machinery. SAMUEL SHELDON. New York, D. Van Nostrand Company. 1900. Pp. 281. $2.50.

Die Lehre von Skelet des Menschen. F. FRENKEL Jena, Gustav Fischer. 1900. Pp. vi + 176. M. 4.50.

Among the Mushrooms. ELLEN M. DALLAS and CAROLINE A. BURGEN. New York, Drexel Biddle. 1900. Pp. xi + 175.

The Principles of Mechanics. FREDERICK SLATE. New York and London, The Macmillan Company. 1900. Pp. x + 299.

Die Ursprüngliche Verbreitung der angebauten Nutzpflanzen. F. Höck. Leipzig, Teubner. 1900. Pp. 78. M. 1.60.

Lehrbuch der vergleichenden mikroskopischen Anatomie der Wirbeltiere. Albert Oppel. Jena, Gustav Fischer. 1900. Part III. Pp. x + 1180 and 10 plates.

A School Chemistry. John Waddell. New York and London, The Macmillan Company. 1900. Pp. xiii + 278.

SCIENTIFIC JOURNALS AND ARTICLES.

Popular Astronomy for October contains an excellent sketch by Professor C. D. Perrine of the late James Edward Keeler, of Lick Observatory, accompanied by his photograph. The opening address by Dr. A. A. Common, F.R.S., F.R.A.S., at the Bradford meeting of the British Astronomical Association for the Advancement of Science is begun in this number and will be concluded in the November number. Also the first part of Kurt Laves' paper on 'The Adjustment of the Equatorial Telescope' is given. Tables for the observation of the planet Eros and an illustrated article upon that planet by the editor, W. W. Payne, together with a résumé of recent work at the Lowell Observatory are important features of this issue, as well as the usual spectroscopic, planet, comet and general notes.

SOCIETIES AND ACADEMIES.

THE PHILOSOPHICAL SOCIETY OF WASHINGTON.

At the meeting of the Society on October 13th, Mr. O. H. Tittmann told in an informal way of some of the incidents of the marking of the provisional boundary between Alaska and the British possessions, at the head of the Lynn Canal, during the past summer.

Dr. Artemus Martin read a paper on 'A Method of Computing the Logarithm of a Number without making use of any Logarithm but that of 10 or some power of 10.' The method in this paper consists in modifying some of the ordinary forms of logarithmic series so that the logarithm used in the computation is the logarithm of 10 or some power of 10.

Dr. T. J. J. See read a paper on the 'System of Uranus.' It combines a statement of some of the recent results of observations, a comparison of these with former results and a critical statement of the uncertainties involved in the present knowledge of the system.

THE ACADEMY OF SCIENCE OF ST. LOUIS.

At the first meeting of the autumn, held on the evening of October 15th, there were sixteen persons present. Mr. William H. Roever, of Washington University, presented an elaborate paper, discussing in detail the subject of the establishment of the method of least squares. Professor F. E. Nipher presented two papers, entitled respectively 'Positive Photography,' with special reference to eclipse work and the frictional effects of railway trains upon the air ; and Mr. C. F. Baker exhibited an interesting collection representing nearly all of the species of fleas thus far known, which he had prepared for the United States National Museum.

Four persons were elected to active membership.

William Trelease,
Recording Secretary.

DISCUSSION AND CORRESPONDENCE.

ARITHMETICAL NOTE.

In the second edition of the *Exercices d'arithmétique* of MM. Fitzpatrick and Chevrel (Paris, Hermann, 1900), there is given the following interesting application of the binary system of notation (p. 490). Russian peasants, when they have to perform a multiplication, in general proceed thus: They divide the multiplicand by 2, and at the same time double the multiplier ; if the multiplicand is odd, they discard the unit remainder and mark the multiplier with a sign. This being done as often as possible, the multipliers affected with the sign are added together to obtain the result. Thus, for example, the multiplication of 35 by 42 proceeds as follows :

35	42 +
17	84 +
8	168
4	336
2	672
1	1344 +

$42 + 84 + 1344 = 1470.$

It is easy enough to construct a similar process, *e. g.*, for the ternary system of nota-

tion; the example might then be worked out in this manner:

35........................ 42 —
12........................ 126
4........................ 378 +
1........................1134 +
378 + 1134 — 42 = 1470;

but the possibility of constructing similar processes throws no light on the origin of such a method among the Russian peasants.

C. A. SCOTT.

CAMPHOR SECRETED BY AN ANIMAL.

TO THE EDITOR OF SCIENCE: Mr. O. F. Cook's article in a recent number of SCIENCE recalls some observations by the late E. D. Cope. Cope wrote (*Trans. Amer. Entom. Soc.*, Vol. 3, May, 1870, pp. 66–67), as follows: "The species of *Spirobolus* and *Julus* discharge a yellowish juice having much the smell of aqua regia and a very acrid taste. The *Spirostrephon lactarius* exudes from a series of lateral pores a fluid which has in its odor a close resemblance to creasote. The *Polydesmus virginiensis* is defended by a fluid which has almost exactly the smell of hydrocyanic acid and is fatal to small animals. *Petaserpes rosalbus* secretes a considerable quantity of a milky substance, which has the perfume of gum camphor."

Quite possibly there are other references to the subject, but I have not examined the literature of the Myriapoda very carefully.

NATHAN BANKS.

EAST END, VA.

A CORRECTION.

TO THE EDITOR OF SCIENCE: In the issue of SCIENCE for October 19th I notice your statement under 'University and Educational News' of my appointment as acting president of Wells College. Permit me to say that a misspelling of my name completely changes it into that of another person. Instead of *Feeley*, it should be *Freley*.

J. W. FRELEY.

BOTANICAL NOTES.

PROLIXITY IN BOTANICAL PAPERS.

WHAT botanist has not groaned in spirit in these recent years over the increasing prolixity of American botanical writers? There was a time when it was the exception for a botanist to write a paper of great length, and some of us were a little ashamed of what appeared to be the inability of botanical writers to prepare papers whose length, at least, would suggest profundity. Doubtless at that time there were fewer men who could write anything better than short notes, and perhaps there was some need of a change. But now, alas, we have learned the lesson only too well. One takes up journal after journal and finds that many of the papers are drawn out through pages and pages until in very weariness he turns to the 'conclusions,' hoping to obtain a summary of the author's results, often to find that here, too, there is such prolixity as to suggest the need of a 'summary' of the 'conclusions.'

Is it not time that botanical teachers gave some instruction in conciseness of statement, while they are making investigators out of the raw material which they find in their classes? Paper and ink do not cost much, and the long-suffering editors of botanical journals have not made, as yet, any audible protest, but we speak for the readers of these long-drawn out papers whose time is too valuable to be given to the absorption and assimilation of the vast mass of excellent but uncondensed matter which now-a-days finds publication. Many a good paper would be much more readable if condensed to half its length, while at the same time it would lose nothing in clearness of statement of all essential facts.

THE STUDY OF PLANT DISEASES.

AN instructive paper by Mr. Galloway, in the 'Yearbook of the Department of Agriculture' for 1899, gives a brief history of the development of the study of plant pathology in the United States. Little has been done by American botanists previous to 1875, and practically nothing at all by the Government. With the establishment of the agricultural experiment stations, an impetus was given to the beginnings made by Professors Farlow, Burrill and Arthur, and about the same time in the Department of Agriculture a beginning was made of what eventually developed into the Division of Vegetable Physiology and Pathology. This was done by the appointment of Professor

Lamson Scribner to be assistant botanist, with instructions to devote himself to the study of plant diseases. For a minor and secondary place in the Division of Botany, this work, thus begun, has grown into a separate division with a large force of trained physiologists and pathologists. With this development in Washington, there has been a corresponding growth in the work in the experiment stations, while in many of the agricultural colleges and larger universities courses of study in plant physiology and pathology have been introduced into the botanical departments. Where but a few years ago so little was done in the study of plant diseases that the term 'plant pathology' was almost unknown, good introductory courses in physiology and pathology are now offered, and increasing numbers of young men are familiarizing themselves with the scientific and practical aspects of the problems involved.

THE ANNUAL SHEDDING OF COTTONWOOD TWIGS.

JUST now (the middle of October) the Cottonwood trees (*Populus deltoides* Marsh.) are shedding their twigs, the ground beneath the large trees being well littered over with fallen twigs of all sizes. This curious phenomenon has been noticed repeatedly, but still it appears not to be generally known, even by botanists. As the autumn advances the cortical tissues of the bases of many of the twigs become so much swollen as to produce bulbous enlargements. At the same time there is a loosening of the woody tissues in the same region, the result being that the woody cylinder is larger in diameter at the base of each affected twig, and the wood-wedges are separated from one another by thicker medullary rays. There appears to be a good deal of longitudinal tension exerted by the swollen cortical tissues, the result being that the woody tissues are pulled asunder, showing a complete transverse fracture of the whole of the woody cylinder. A breeze now easily fractures the cortical tissues and the twig drops to the ground.

There is much apparent waste in this shedding of these twigs, since they invariably have large, well-formed terminal buds and generally a good many lateral buds also. Among the latter one often finds well-grown flower buds. These facts show that the twigs which are shed are not the feeble and dying ones, but are among the most vigorous and active on the trees. It is an interesting fact that the Tamarisks (*Tamarix* sp.), which are held by some botanists to be closely related to the Poplars, shed their twigs by exactly the same device as that described above. In the Tamarisks the shedding of the twigs is a part of the annual process of defoliation, their leaves being so small that it appears to be less trouble and expense to drop twig and all than to separate every individual leaf. Possibly in the Cottonwoods, with their large leaves, we have a survival of the Tamarisk twig-shedding habit long after its original significance has disappeared.

THE IMMEDIATE EFFECT OF POLLEN.

FOR a long time it has been known that in the crossing of some plants the pollen seems to produce an effect upon more than the embryo, in other words, that not only the embryo but other structures, also, show evidences of hybridity. Focke named this phenomenon *xenia* in a paper published nearly twenty years ago, and this is the term now used by writers of papers on this subject. The latest paper is an exceedingly interesting one by H. J. Webber: 'Xenia, or the Immediate Effect of Pollen, in Maize,' published as a bulletin (No. 22) of the Division of Vegetable Physiology and Pathology of the United States Department of Agriculture. In it an attempt is made to throw light upon the real nature and meaning of the phenomenon. Many experiments were made by him to determine whether xenia actually takes place in maize, with the result that its occurrence is no longer to be doubted. It is shown, moreover, that this immediate effect of the pollen is limited to the endosperm of the maize kernel. Thus where a change of color occurs in the hybrid, this color is in the endosperm cells, and furthermore, where the color is in the pericarp (as in the variety known as Red Dent) no change in color takes place.

The explanation suggested by DeVries and Correns in papers published almost simultaneously in December, 1899, that xenia is the result of double fecundation is adopted by Mr. Webber without modification. In fact the same

explanation had suggested itself to him early enough in 1899 to enable him to make a number of experiments that year, with a view to obtaining evidence in regard to it. This theoretical explanation, in short, is as follows: As is now admitted, in the process of fecundation (in some plants, at least) not only is there a union of one of the generative nuclei of the pollen tube with the egg nucleus, but also, there is a union of the second generative nucleus with the embryo-sac nucleus. As the endosperm develops from this nucleus thus fecundated, it is clearly a hybrid organism also. In other words, in the fecundation of the egg a hybrid sporophyte is produced, but at the same time the supporting gametophyte (the endosperm) is itself developed as a hybrid. This is possible because of the tardy development of the gametophyte tissue, which is so delayed that actually it is formed simultaneously with that of the sporophyte which it bears, and which it should precede.

CHARLES E. BESSEY.
THE UNIVERSITY OF NEBRASKA.

NEW YORK BOTANICAL GARDEN.

IMPROVEMENTS in the New York Botanical Garden are going steadily forward. A contract amounting to $22,000 for grading and roadways near the Museum is approaching completion, and a series of working greenhouses is now under construction in the eastern part of the Garden in a locality little frequented by visitors. These houses comprise two main ranges 20 by 60 feet, storage rooms, potting sheds and an independent heating plant, in which the open hot water system will be used.

The New York Central and Hudson River Railroad is building a new passenger station at the Bedford Park entrance to the Garden. The new station will be of stone and brick costing about $40,000. The offices will be located on the western side of the tracks, connected by a tunnel with the extensive passenger shelters and waiting rooms on the eastern side which open directly into the plaza. The name of the station will be changed to Bronx Park (Botanical Garden) upon completion of the new building which will save much confusion to visitors.

Professor L. M. Underwood spent the summer in investigations upon American ferns in the British Museum, Kew Gardens and the Cosson Herbarium in Paris. The Cosson Herbarium contains the Feé collection, formerly owned by Emperor Dom Pedro of Brazil. The Feé collection has the largest and best set of West Indian ferns in existence.

Other exploration work was carried out in connection with the Garden is as follows: Dr. Rydberg accompanied by Mr. F. K. Vreeland made extensive collections in the Sierra Blanca in southeastern Colorado; Dr. D. T. MacDougal explored the Priest River Forest Reserve, also carrying out investigations under a grant from the American Association; Dr. C. C. Curtis made a series of collections in western Wyoming, Professor F. E. Lloyd in cooperation with Professor Tracy visited the islands in the Mississippi delta; Messrs R. M. Harper and Percy Wilson made collections in Georgia, and Dr. M. A. Howe investigated the marine and land flora of Bermuda and the coast of Maine, also carrying out the terms of a grant from the Peabody fund; Dr. and Mrs. N. L. Britton made a brief tour in the Adirondacks, securing many living specimens of alpine plants for the grounds.

Dr. N. L. Britton is now in Europe for the purpose of securing exhibits from the Paris Exposition and negotiating for the purchase of several herbaria.

Contributions for the conservatories have been received from many sources, the most valuable of which are those given by Miss Helen Gould, Mrs. F. L. Ames and Siebrecht and Son.

The fall lecture course now in progress has been announced as follows:

October 13th. 'Autumn Flowers,' by Mr. Cornelius VanBrunt.

October 20th. 'Evergreen Trees,' by Professor F. E. Lloyd.

October 37th. 'Freezing of Plants,' by Dr. D. T. MacDougal.

November 3d. 'Evolution of Sex in Plants,' by Professor L. M. Underwood.

November 10th. 'Poisonous Plants which Live in our Bodies, and how we contend against them,' by Professor H. H. Rusby.

November 17th. 'The Sedges,' by Professor N. L. Britton.

SCIENTIFIC NOTES AND NEWS.

An oil portrait of Professor Henry A. Rowland, of Johns Hopkins University, painted by Mr. Harper Pennington, has been presented to the University and hung in the large lecture room in the physical laboratory.

Dr. Oscar Loew, for some time expert physiologist in the Division of Vegetable Physiology and Pathology of the United States Department of Agriculture, has resigned in order to accept a position in the Agricultural College of the Imperial University of Tokyo, Japan, as lecturer on physiological chemistry. By his resignation the Department loses one of its best investigators in the special field which he occupied. He sailed from Vancouver on October 8th.

Dr. Oustalet has been appointed professor of zoology in the Natural History Museum at Paris, as successor to the late Professor Milne-Edwards.

Professor Bashford Dean, of Columbia University, is spending his Sabbatical year in zoological work in Japan. He has begun his work at the Marine Biological Station of the Government on the east coast.

The expedition to Labrador under Professor Delabarre of Brown University and Dr. Daly of Harvard University has returned, having made numerous observations and collections in Labrador.

The Gold Medal of the Paris Exposition was awarded to Professor A. S. Bickmore, of the American Musem of Natural History, and his assistants especially for the photographic slides illustrating the lectures: 'Across the American Continent' and 'The Hawaiian Islands.' The 'wide system of free education' carried on by this department in cooperation with the State Board of Education was especially mentioned in the award. Professor Bickmore was moreover invited to give two public lectures in the Trocadero illustrating his method of visual instruction.

Dr. B. M. Duggar, of Cornell University, has been elected a member of the German Botanical Society.

Professor H. V. Hilprecht, who has been carrying on explorations in Babylonia, is expected to return to the University of Pennsylvania at the end of the present month.

Mr. Frank M. Chapman, assistant curator of the Department of Vertebrate Zoology, of the American Museum of Natural History, will give a special course of six lectures on birds, at the Museum on Saturday afternoons at three o'clock, beginning November 10th.

Dr. Robert Koch, who is employed by the German Government to investigate tropical diseases, arrived at Marseilles on October 19th from German New Guinea by way of Hong-Kong. He is on his way to Berlin, where he will present to the Academy of Medicine the result of fifteen months' study of malaria in New Guinea, Java and adjacent German territories.

It appears that Elias Howe, the inventor of the sewing machine, is not to be included among the 30 eminent Americans of the Hall of Fame of New York University. A mistake was made in counting up the votes, Howe receiving 47 instead of 53 as originally announced. This leaves 21 panels to be filled two years hence.

The house in which Samuel F. B. Morse lived from 1864 until 1872, at No. 5 West 22d street, New York City, has been torn down and an office building erected in its place. The original house contained a bronze commemorative tablet which was last week moved to the new building. The tablet bears the inscription: "In this house S. F. B. Morse lived for many years and died." Under it has been added: "This tablet was removed from building formerly on this site and replaced A. D. 1900."

Sir Henry Wentworth Dyke Ackland, for many years regius professor of medicine at Oxford, and Radcliffe Librarian, died on October 16th at the age of 85 years. Sir Henry was appointed reader in anatomy at Oxford in 1845 and regius professor of medicine in 1858, resigning the chair in 1894.

A dispatch from Daker, Senegal, states that M. Paul Blanchet, the well-known French explorer, has died of yellow fever. He was about to embark on his return to France.

The positions of assistant in zoology and in mineralogy in the State Museum at Albany

will be filled by civil service examination on or about November 10th. The salaries of these positions are $1,200 and $900, respectively. In the examinations, experience and education count three, and the answers to questions on the science seven points. In zoology the examination will have special reference to vertebrate and systematic zoology. The positions are open only to men over twenty-one years of age who must be citizens of New York State.

THE government of the Canton of Zurich has voted to increase its annual subsidy to the Concilium Bibliographicum. In the preamble it is stated that this is done in recognition of the high value of the work of the Concilium Bibliographicum, in the hope that others may aid in securing for the undertaking a firm financial basis, with the purpose of offering the full support permitted by the funds at our disposal, be it enacted, etc. This vote which was taken August 15th has led to a similar decision on the part of the town of Zurich, and now a bill has been introduced by the Department of Interior providing for quintupling the federal subsidy and for placing the Concilium under the more immediate control of the Swiss Government. The ultimate result of these votes will doubtless be the expansion of the field of activity of the Concilium, so as to include botany, anthropology, etc., but for the time being all will be done to render the bibliographies now in existence more complete and to issue them more promptly.

THE Duke of Abruzzi has given the *Stellar Polare*, the vessel in which he made his recent exploring trip to the North, to the Italian Navy. She is to be kept in the naval arsenal at Spezia as a souvenir.

MR. ANDREW CARNEGIE has presented £10,000 to the town of Hawick, Roxburgh County, Scotland, for a public library.

THE late Edwin H. Bugbee of Danielson, Connecticut, bequeathed $15,000 and his private library to the public library of that town.

THE fine new lecture hall of the American Museum of Natural History will be opened with appropriate exercises on Tuesday, October 30th. The president of the institution, Mr. Morris K. Jesup, will receive invited guests from 3 until 6 o'clock. At 4 o'clock some views of the Paris Exposition will be exhibited in the lecture hall by Professor Bickmore. Admission to the new halls in the west wing and an inspection of their archeological and ethnological collections will also be permitted.

THE Library Building of the Historical Society of the State of Wisconsin was dedicated on October 19th. The building, which is practically part of the University of Wisconsin, has been erected at a cost of $575,000.

WE learn from the *Botanical Gazette* that the Division of Vegetable Physiology and Pathology of the Department of Agriculture has secured a table at the Marine Biological Laboratory at Woods Holl for the use of its staff during the summer months.

THE British Museum (Natural History) has started a collection of 'sports' and 'monstrosities' among insects and will be glad to receive contributions from entomologists.

THE new dynamometer car which the Illinois Central Railroad has been building for the Mechanical Department of the University of Illinois, is now ready for use. It is fully equipped and is fitted up with every convenience. The car will be put into active service immediately on a series of tests begun some time ago by the Illinois Central.

THE collection of rare African antelope skins received in exchange from the Field Columbian Museum are now all mounted and placed on exhibition in the American Museum of Natural History.

As the daily papers have very fully reported, Count von Zeppelin's air-ship made two ascents. On October 17th it stayed in the air about an hour and was apparently able to make some headway against a light breeze. It could not, however, return to its starting point.

THE German Anthropological Society held its thirty-first annual meeting at Halle from September 23d to 27th.

THE new laboratories at King's College, which have been in course of construction during the past year, are finished and ready for occupation, and the opening ceremony has been fixed for Tuesday, October 30th. Lord

Lister, P.R.S., will deliver an address after which the laboratories will be open for inspection. We learn from the *British Medical Journal* that although a considerable sum has already been subscribed toward defraying the cost of the building, much has still to be raised, and it is hoped that those interested in higher education may see their way to assist the Council to defray the debt. It is also hoped that funds may be available from the reconstituted University of London for the same purpose. The movement for the extension of the College primarily arose from the difficulties experienced by the professors of bacteriology and physiology in dealing with the great increase in their classes which has occurred during recent years, and at the same time to afford space to those who wish to prosecute original research. The already spacious bacteriological laboratory has been nearly doubled in size and a complete bacteriological library added to it. The physiological laboratory is entirely new, the rooms are handsome, well lighted and fitted in a most complete way. The old physiological laboratory has been absorbed by the extension into it of the anatomical department which was previously much cramped for room. The museum has been completely rearranged; the old museum now becomes the architectural department. Geology and botany are provided with new laboratories and other departments which have benefited by the change are physics, materia medica and State medicine.

THE *London Standard* states that Dr. Sven Hedin, according to the latest reports, reached Abdal, on the Tarim River, in eastern Turkestan, on June 27th. He states that the Tarim is the largest river in the interior of Asia. He surveyed the river from Arghan to Abdal in a ferryboat. From Jeggeli-ku, where the river becomes a multitude of small lakes, he continued his journey in a craft made up of three canoes lashed together, with a deck surmounted by a felt tent. In the beginning of March he made an excursion from the Yangi-kol, where he had his winter camp, to the southern slope of the Karruk-tagh Mountains, where he surveyed the Kumdarya bed of the Tarim which is now dry. In the neighborhood he found the marks of a large dried-up lake, probably the old Lob-Nor, which lies east of the present Lob-Nor, or rather the four lakes discovered by him in 1896. The dry soil was covered with a thick layer of salt and millions of mussel shells, while the banks held many withered reeds, dead trees, consisting exclusively of poplars and ruins of houses, fortifications, temples, etc., which were often adorned with artistic wood carvings. Dr. Hedin intended to return to this region in the autumn. In the middle of the desert he found and investigated a larger lake of salt water and then returned to his winter camp. During his stay at Abdal he wrote down several songs sung for many generations by the Lob-Nor men when fishing. When he left this district the thermometer registered forty-two degrees above zero, Celsius; whereas it falls to thirty-two degrees below zero during the winter.

WE learn from the *American Museum Journal* that the photographs collected by members of the Jesup North Pacific Expedition will be reproduced by the heliotype process in large quarto form, and published under the title 'Ethnographical Album of the North Pacific Coasts of America and Asia.' It is intended to issue the album to subscribers only, in parts of at least 24 plates annually, the whole series to embrace 120 plates. Part I., consisting of 28 plates, illustrating Indian types from the interior of British Columbia, has already appeared.

THE British Office of Woods and Forests has purchased from the Duke of Beaufort the Tintern Abbey estate which comprises the famous abbey and 5,334 acres of land. This area includes nearly 3,000 acres of woodland, the most picturesque portions of which are the wooded hills and slopes with a frontage of eight miles on the River Wye. The estate is near the extensive woods of the Crown in the Forest of Dean. At the same time the Crown has also purchased the whole of the Duke's farms surrounding Raglan Castle, 3,169 acres in extent.

DURING the past summer the division of soils of the department of agronomy at the University of Illinois has undertaken a study of the soils of Illinois. With this end in view, over

five hundred samples have been collected from various parts of the State. These samples, which are being prepared for permanent specimens and for purposes of study, represent a large proportion of the many different types of soil which are to be found within the State. It is proposed to study these soils mechanically, chemically and biologically, to determine the individual properties peculiar to each different type, and the proper methods of handling and cropping best adapted to each. The work which has been done indicates that there are numerous problems of a fundamental character and of vital importance which are demanding the attention of the farmers of the State. Not the least among these is the question of soil exhaustion which is beginning to force itself upon the attention of the people of some parts of the State in such a way that its importance and influence are being seriously felt.

DURING the last few years, several thousand samples of drinking water from various ordinary house wells throughout the State have been sent to the State University of Illinois, for analysis and report as to quality. By far the greater proportion of these water samples have proved, upon analysis, to be contaminated with drainage from refuse animal matters and consequently have been regarded with grave suspicion, or have been pronounced unwholesome for use as drink. The present prevalence of typhoid fever in a number of places in the State makes it desirable that the public should remember that the State has made provision for the examination of all suspected waters. It is not practicable to isolate actually the typhoid fever germs or to prove directly their absence from waters submitted for analysis; this for the reason that the work entails more labor and time than is made available by the means which the State provides. However, the chemical examination is sufficient ordinarily to show whether the water is contaminated with house drainage or drainage from refuse animal matters or whether it is free from such contamination. Any citizen of the State may have examinations made of the drinking water in which he is interested, free of charge, by applying to the Department of Chemistry of the State University.

The *Journal* of the Board of Trade, as quoted by the London *Times*, states that deposits of sulphur have been discovered in Russia only in recent years, and that small works for treating the ore have been established at various times, the largest being in Daghestan, in the northern Caucasus. The chief output of these was in 1888, when it reached 1,500 tons, but since then the works have been closed. The deposits in Daghestan are known to be extensive, while the ore contains 20 per cent. of sulphur, and the geological formation is very similar to that in which the Sicilian deposits occur. But the situation is unfavorable, being a mountainous district 4,500 feet above the level of the Caspian, from which it is separated by numerous steep ridges which are difficult to traverse, even for mules. In Russia now only two sulphur works are in operation, and they produce only 1,000 tons a year, while the consumption of sulphur in the country, owing to the growth of the petroleum industry, is about 20,000 tons. The vast bed lately discovered in Trans-Caspia is one of the richest in the world, and will undoubtedly prove of great importance. It comprises several distinct mounds in an area of 23 square miles, and is situated 100 miles from Khiva, near the Amu Daria river and about 170 miles from Askabad on the Trans-Caspian railway. None of the minerals discovered in the province are being worked, and sulphur is doubtless the most important of these. The mounds above mentioned are dome shaped, about 300 feet high, the sulphur being practically exposed, while the ore is generally sandstone and contains on an average 60 per cent. of sulphur. It is estimated that the mounds contain over 9,000,000 tons of sulphur, and the local circumstances are said to be favorable to work on a large scale. Labor is plentiful and cheap, and transportation could be effected by means of a narrow-gauge line to Askabad, and this could be extended beyond the deposits to Khiva, where wool and other commodities may be had in quantities sufficient to make the line profitable. Nor, it is said, are there any engineering difficulties in the construction of such a line.

WE have already called attention to the comparatively few awards made at Paris for Amer-

ican machinery. The *Electrical World* holds that the country has been unfairly treated. It says: "In electricity, Austria, with 25 entries, had 5 grand prizes and 17 gold medals. The United States, with 283 entries, had 6 grand prizes and 23 gold medals. In machinery, Switzerland, with 14 entries, got 9 grand prizes and 15 gold medals. The United States, with 282 entries, got a paltry 10 grand prizes and 26 gold medals. The relative proportions are preposterous. We refuse to believe that American machinery, now sweeping Europe, is inferior to the Swiss or Austrian in any such degree as this implies."

UNIVERSITY AND EDUCATIONAL NEWS.

MRS. JANE K. SATHER, of San Francisco, has given $1000,000 to the University of California.

IT is reported that three alumni of Yale University have offered to subscribe each $100,000 for the memorial building in case the further sum of $300,000 is secured.

THE United States Supreme Court has finally rendered a decision sustaining the trust left by Mrs. Katherine M. Garcelon of Oakland, California. After long and expensive litigation, the wishes of Mrs. Garcelon will be carried into effect and three-fifths of the sum will be used to establish a hospital in Oakland and two-fifths will revert to Bowdoin College which will receive about $500,000.

THE Bartram memorial library of botanical books has been presented to the library of the University of Pennsylvania.

MR. R. F. BALK, of Cincinnati, has given to the University of Cincinnati his collection of specimens of natural history said to be of considerable value.

A NEW bacteriological laboratory has been built for the University of Melbourne at a cost of $20,000.

THE Department of Geology of the University of Chicago had three parties of students in the field during the past summer. Two of these parties were in Wisconsin, one during July and one during August, while the third party was in the West, along the line of the Great Northern Railway. The principal stops made by the third party were at Midvale and Lake McDonald, Montana, and at Lake Chelan in Washington. A trip was also made into the Kootenai region of British Columbia. Each party was in the field four weeks, and the total number of students participating was between thirty and forty.

THE registration at Yale University is 2,474, a decrease of 43 as compared with last year. The Sheffield Scientific School has, however, an increase of 36 students.

SIR MICHAEL FOSTER has been reelected member of the British Parliament, representing the University of London, without opposition; Sir John Batty Tuke has been returned under the Universities of Edinburgh and St. Andrews also without opposition.

THE daily papers report that eight of the former professors of the reorganized University of Havana are to receive pensions of $1,200 a year each during the term of the military occupation.

THE Rev. Dr. Robert Sheppard, professor of history and political economy at Northwestern University, has been appointed president of the University.

EDWARD M. PAXSON, ex-Chief Justice of the Supreme Court of Pennsylvania, has been elected president of the Medico-Chirurgical College in Philadelphia.

WILLIAM T. HORNE and Albert T. Bell, fellows in botany in the University of Nebraska, have resigned, the former to accept a position in Kadiak, Alaska and the latter an instructorship in the High School of Lincoln, Nebr. Mr. Horne expects to make collections of the flora of Kadiak Island for study on his return a year or two hence. Miss Daisy F. Bonnell, of the class of 1899, has been appointed fellow in botany.

PROFESSOR J. W. FRELEY has been appointed acting president of Wells College.

DR. SPENCER W. RICHARDSON, lecturer on mathematical physics at University College, Nottingham, has been elected principal of Hartley College and professor of physics.